



POWER EXTENSION PACKAGE (PEP) SYSTEM DEFINITION EXTENSION

Orbital Service Module Systems Analysis Study

VOLUME 4
PEP Functional Specification

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A handwritten signature in cursive script, reading "D. C. Wensley".

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PREFACE

The extension phase of the Orbital Service Module (OSM) Systems Analysis Study was conducted to further identify Power Extension Package (PEP) system concepts which would increase the electrical power and mission duration capabilities of the Shuttle Orbiter. Use of solar array power to supplement the Orbiter's fuel cell/cryogenic system will double the power available to payloads and more than triple the allowable mission duration, thus greatly improving the Orbiter's capability to support the payload needs of sortie missions (those in which the payload remains in the Orbiter).

To establish the technical and programmatic basis for initiating hardware development, the PEP concept definition has been refined, and the performance capability and the mission utility of a reference design baseline have been examined in depth. Design requirements and support criteria specifications have been documented, and essential implementation plans have been prepared. Supporting trade studies and analyses have been completed.

The study report consists of 12 documents:

- Volume 1 Executive Summary
- Volume 2 PEP Preliminary Design Definition
- Volume 3 PEP Analysis and Tradeoffs
- Volume 4 PEP Functional Specification
- Volume 5 PEP Environmental Specification
- Volume 6 PEP Product Assurance
- Volume 7 PEP Logistics and Training Plan Requirements
- Volume 8 PEP Operations Support
- Volume 9 PEP Design, Development, and Test Plans
- Volume 10 PEP Project Plan
- Volume 11 PEP Cost, Schedules, and Work Breakdown Structure Dictionary
- Volume 12 PEP Data Item Descriptions

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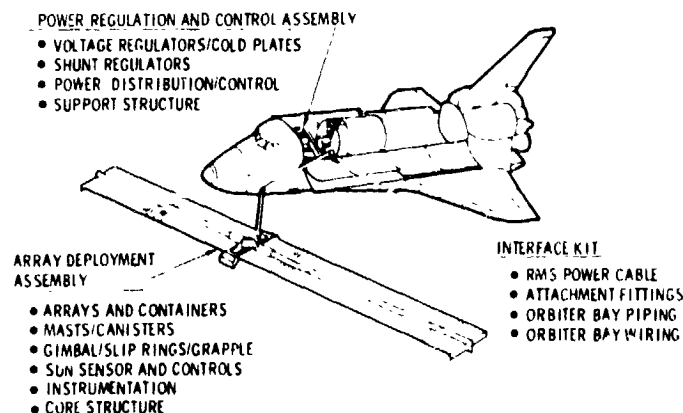
FOREWORD

The Power Extension Package (PEP) is a solar electrical power generating system to be used on the Shuttle Orbiter to augment its power capability and to conserve fuel cell cryogenic supplies, thereby increasing power available for payloads and allowing increased mission duration. The Orbiter, supplemented by PEP, can provide up to 15 kW continuous power to the payloads for missions of up to 48 days duration.

When required for a sortie mission, PEP is easily installed within the Orbiter cargo bay as a mission-dependent kit. When the operating orbit is reached, the PEP solar array package is deployed from the Orbiter by the remote manipulator system (RMS). The solar array is then extended and oriented toward the sun, which it tracks using an integral sun sensor/gimbal system. The power generated by the array is carried by cables on the RMS back into the cargo bay, where it is processed and distributed by PEP to the Orbiter load buses. After the mission is completed, the array is retracted and restowed within the Orbiter for earth return.

The figure below shows the PEP system, which consists of two major assemblies -- the Array Deployment Assembly (ADA) and the Power Regulation and Control Assembly (PRCA) -- plus the necessary interface kit. It is nominally installed at the forward end of the Orbiter bay above the Spacelab tunnel, but can be located anywhere within the cargo bay if necessary. The ADA, which is deployed, consists of two lightweight, foldable solar array wings with their containment boxes and deployment masts, two diode assembly interconnect boxes, a sun tracker/control/instrumentation assembly, a two-axis gimbal/slip ring assembly, and the RMS grapple fixture. All these items are mounted to a support structure that interfaces with the Orbiter. The PRCA, which remains in the Orbiter cargo bay, consists of six pulse-width-modulated voltage regulators mounted to three cold plates, three shunt regulators to protect the Orbiter buses from overvoltage, and a power distribution and control box, all mounted to a support beam that interfaces with the Orbiter.

PEP is compatible with all currently defined missions and payloads and imposes minimal weight and volume penalties on these missions. It can be installed and removed as needed at the launch site within the normal Orbiter turnaround cycle.



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CONTENTS

Section 1	SCOPE	1
Section 2	APPLICABLE DOCUMENTS	3
	2.1 Government Documents	3
	2.2 Non-Government Documents	5
Section 3	REQUIREMENTS	7
	3.1 System Definition	7
	3.2 Characteristics	21
	3.3 Design and Construction Standards	28
	3.4 Functional Area Characteristics	33
	3.5 Ground Support	51
	3.6 Precedence	54
Section 4	QUALITY ASSURANCE PROVISIONS	57
	4.1 General	57
	4.2 Quality Assurance Inspections	60
Section 5	PREPARATION FOR DELIVERY	63
	5.1 General	63
	5.2 Preservation and Packaging	63
	5.3 Packing	63
	5.4 Marking	63
Section 6	NOTES	65
	6.1 Abbreviations and Acronyms	65
	6.2 Definitions	66
Appendix I	PEP-RELATED INTERFACES	69

Section 1

SCOPE

This document defines the functional, performance, design and test requirements for the Orbiter Power Extension Package (PEP) System and its associated ground support equipment (GSE).

Section 2
APPLICABLE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superceding requirement.

Specifications:

MSFC-SPEC-504A	1 Nov 77	Welding, Aluminum Alloys
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Standards:

MIL-STD-129H	3 Jan. 78	Marking for Shipment and Storage
MIL-STD-453B	31 Mar. 77	Inspection, Radiographic
MIL-STD-454F	15 Mar. 78	Standard, General Requirements for Electrical Equipment
MIL-STD-721B	10 Mar. 70	Definitions of Effectiveness
Notice 1		Terms for Reliability, Maintainability, Human Factors, and Safety
MIL-STD-1472B	31 Dec 74	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-C-6021H	3 Jun 76	Casting, Classification and Inspection of
MIL-W-6858	28 Mar 78	Welding, Resistance, Aluminum, Magnesium, Non-Hardening Steels or Alloys, Nickel Alloys, Heat Resisting Alloys, and Titanium Alloys, Spot and Seam
MIL-I-866B	30 Jan 69	Inspection, Penetrant, Method of
MIL-I-8950B	7 Jul 70	Inspection, Ultrasonic, Wrought Metals, Process for
MIL-A-21180C	19 Jul 76	Aluminum Alloy Castings, High Strength

Drawings:

ICD-2-05101B	17 Dec 75	Space Shuttle ICD, Level II, Shuttle Vehicle/Spacelab Structural/Mechanical Interfaces
ICD-2-05301		Shuttle Vehicle/Spacelab Avionics Interfaces
ICD-2-19001 (Attachment 1 to JSC) 07700, Vol. XIV, Change 27)		Level II Shuttle Orbiter/Cargo Standard Interfaces
IDD SOD79117	21 Jun 79	Interface Definition Document - Power Extension Package

Other Publications:

Handbooks:

NHB 1700.7	May 79	Safety Policy and Requirements for Payloads Using the Space Transportation System (STS)
NHB 5300.4 (3A-1)	Dec 76	Requirements for Soldered Elec- trical Connections
NHB 6000.1C	Jun 76	Requirements for Packaging, Han- dling and Transportation for Aero- nautical and Space Systems, Equipment, and Associated Compo- nents
NHB 8060.1A	Feb 74	Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion

Documents:

JSC-SE-R-0006A	29 Mar 76	JSC Requirements for Materials and Processes
JSC-SP-R-00^2A	Sep 74	Vacuum Stability Requirements of Polymeric Material for Spacecraft Application

NASA/JSC SW-E-0002 Rev. B	6 Jan 76	Space Shuttle Program Ground Support Equipment General Design Requirements
JSC-07636		Space Shuttle Lightning Protection Criteria Document
JSC7700 Vol. I		Program Description and Requirements Baseline
JSC-07700 Vol. VII	15 Dec 78	Space Shuttle Commonality Management
JSC7700 Vol. XIV, Change 28	23 Mar 79	Space Shuttle System Payload Accommodation
MPD 164	21 Mar 57	Welding, Arc and Gas; for Fabricating Ground Equipment for Rockets and Guided Missiles
NASA-SP-8063	Jun 71	Lubrication, Friction and Wear, Space Vehicle Design Criteria/Structures
QQ-A-367H RMS-1.160A (SPAR Report)	6 Dec 76	Aluminum Alloy Forgings SRMS Phase D NRCC/SPAR Support Coupled Dynamics Analysis

2.2 NON-GOVERNMENT DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superceding requirement.

Specifications:

1D23452 (McDonnell Douglas Aeronautics Company)	Jul 79	PEP Environmental Specification
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Section 3 REQUIREMENTS

3.1 SYSTEM DEFINITION

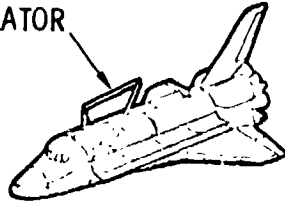
3.1.1 General Description

The Power Extension Package (PEP) is a solar array power system used to augment the Orbiter's fuel cell/cryogenic power system and extend the Orbiter's mission duration capability. When illuminated by the sun, PEP provides most of the electrical power for use by the Orbiter and its payloads. During the dark side of the orbit, the solar array is dormant and the Orbiter fuel cells supply the full power.

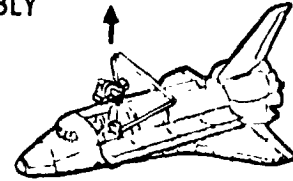
The PEP consists of: (1) solar array and supporting equipment which are deployed by the Remote Manipulator System and (2) power conditioning equipment which remains in the Orbiter cargo bay during the mission. The PEP solar array power system has two arrays comprised of photovoltaic solar cells mounted on blankets of a lightweight, flexible substrate which are deployed by two coilable or articulated masts. When not operational, the arrays are retracted and folded into compact array storage boxes. The entire assembly is stowed in the Orbiter cargo bay during launch and descent. Figure 1 displays a typical sequence for on-orbit deployment of the array assembly using the Orbiter's Remote Manipulator System (RMS). In step 4 the masts are used to deploy the two arrays. The assembly remains attached to the RMS during orbital operation. Electrical power, derived by orienting the array normal to the sun vector using an independent PEP control system, is transmitted over cables to the PEP power regulation and distribution equipment which remains in the cargo bay during the mission. At that point, it is conditioned and interconnected with the Orbiter's main busses. The resulting power is usable by both the Orbiter and its payloads. To stow the PEP for return to earth, the solar array is retracted and the RMS brought to full activation. The RMS operator then guides the array assembly into the stowage position in the Orbiter bay.

STEP 1 - GRAPPLE ARRAY

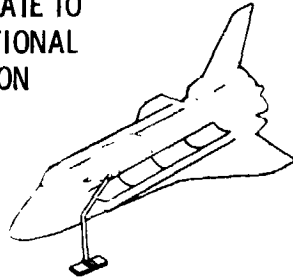
REMOTE MANIPULATOR
SYSTEM



STEP 2 - UNSTOW ARRAY
DEPLOYMENT
ASSEMBLY



STEP 3 - TRANSLATE TO
OPERATIONAL
LOCATION



STEP 4 - LOCK RMS
AND DEPLOY ARRAY

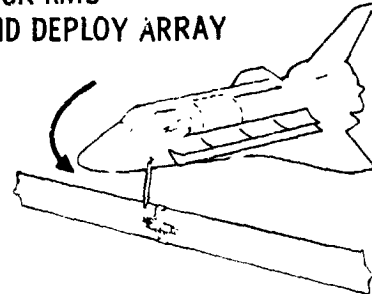


Figure 1. Deployment Sequence

The PEP system is grouped into four functional areas:

A. Electrical Power Subsystem- Generates electrical power and conditions, controls and distributes that power to the Orbiter busses for use by the Orbiter and its payloads.

B. Structural/Mechanical Subsystem - Provides support and grouping for other PEP subsystems and transfers ground and flight loads to the Orbiter structural interface. In addition, it performs the functions of array deployment, retraction, latching, suspension, tensioning and gimbaling.

C. Avionics and Control Subsystem - Performs electronic equipment activation, initialization, position and rate control of deployed elements, and monitoring of equipment status as well as provides crew interfaces for PEP command and status display.

D. Thermal Control Subsystem - Maintains PEP equipment within temperature limits using active and passive means.

3.1.2 PEP Mission

The mission of the Power Extension Package (PEP) is to augment the Orbiter power and duration capability for sortie missions. Spacelab missions will especially be able to take advantage of this capability. Early planned Spacelab missions are currently power and duration limited - the addition of

PEP will not only alleviate these constraints, but provide the capability for long-term missions up to 48 days. This capability is added by the PEP solar array which increases the power level and also the duration by reducing the fuel cell cryogen expenditures during the solar illuminated portion of each orbit. PEP doubles the electrical power available to Orbiter payloads (from 7 to 15 kW) and increases the duration from 6 days to 48 days. PEP can accommodate all missions from 28.5 to 104° inclination and from 100 to 600 n.mi. altitude.

The increased power and duration capability will allow improved utilization of payload equipment and increased mission duration will result in additional data return for a given instrument set. It will also allow the placement of additional payload equipment on a given flight. The net effect is to increase payload utilization of the Orbiter which can reduce the number of scheduled flights.

3.1.3 Operational Concept

When the array is fully illuminated by the sun, PEP provides up to 26 kW of electrical power. This is combined with approximately 3 kW from the Orbiter's fuel cells to deliver a total continuous power level of 29 kW at the Orbiter's main busses. During the dark side of the orbit, the solar array is dormant and the fuel cells provide the full power of up to 29 kW. The power developed by the array is conditioned by the PEP regulation and distribution equipment to a nominal 33 volts and distributed to the Orbiter's main busses. During typical operations, the Orbiter will use 14 kW leaving 15 kW available for payload use.

When needed, PEP will be installed in the Orbiter's payload bay. The nominal installation position is at the forward end of the bay (above the short tunnel of the payload bay) for launch to orbit. PEP may be located along the payload bay within reach of the RMS to meet alternate payload requirements (e.g., all Spacelab pallets). At the selected point in the mission timeline, PEP deployment is accomplished using the RMS under operator control from the Aft Flight Deck position with viewing through the Orbiter windows.

When deployed to the nominal operating position, RMS joint brakes are locked and the RMS remains quiescent (idle mode). During normal operation, loads induced on the RMS shall not result in joint back drive. Once the RMS is in

the idle mode condition, the solar arrays are extended and independent PEP controls are used to track the sun position and maintain the arrays normal to the sun vector. Orbiter power (not to exceed 200 watts) is used to drive the PEP control elements for these operations. Once the arrays are properly positioned, electrical power can be delivered to the power conditioning equipment. The PEP regulators limit the Orbiter fuel cell power output during sunlight conditions and permit normal fuel cell operation during eclipse periods.

PEP design shall permit normal RMS operation when the array assembly is stowed in the Orbiter. Further, the PEP design shall incorporate provisions for checkout and monitoring on the ground and during flight. PEP heat rejection shall use the Orbiter aft cold plate fluid loop.

Initially, the PEP will be utilized with the Orbiter from the Eastern Test Range (ETR). It is expected that missions launched from the Western Test Range (WTR) will be implemented in the future.

3.1.4 System Configuration

Figure 2 presents a top level functional block diagram of the PEP. The figure identifies the primary functions of the electrical power, structural/mechanical, avionics and control and thermal control subsystems as well as the significant interrelationships between these subsystems.

A representative configuration for the PEP concept is illustrated in Figure 3. The major elements of the system, shown stowed in the Orbiter cargo bay, are the Array Deployment Assembly, Power Regulation and Control Assembly and Interface Kit. Table 1 relates these major assemblies to the four PEP functional subsystems.

The Array Deployment Assembly (ADA) consists primarily of two flexible substrate solar cell arrays, coilable or articulated masts used for deployment and retraction of each array, and a central support structure for the arrays, auxiliary equipment and Orbiter attachment fittings. The two independently deployed solar arrays are housed in separate box assemblies. In this configuration, the ADA is mounted transversely in the cargo bay. For array deployment, the canisters are each rotated until perpendicular to the blanket box assemblies. The ADA is supported in the cargo bay on trunnions and is restrained by remotely releasable retention latches. The ADA includes a grap-

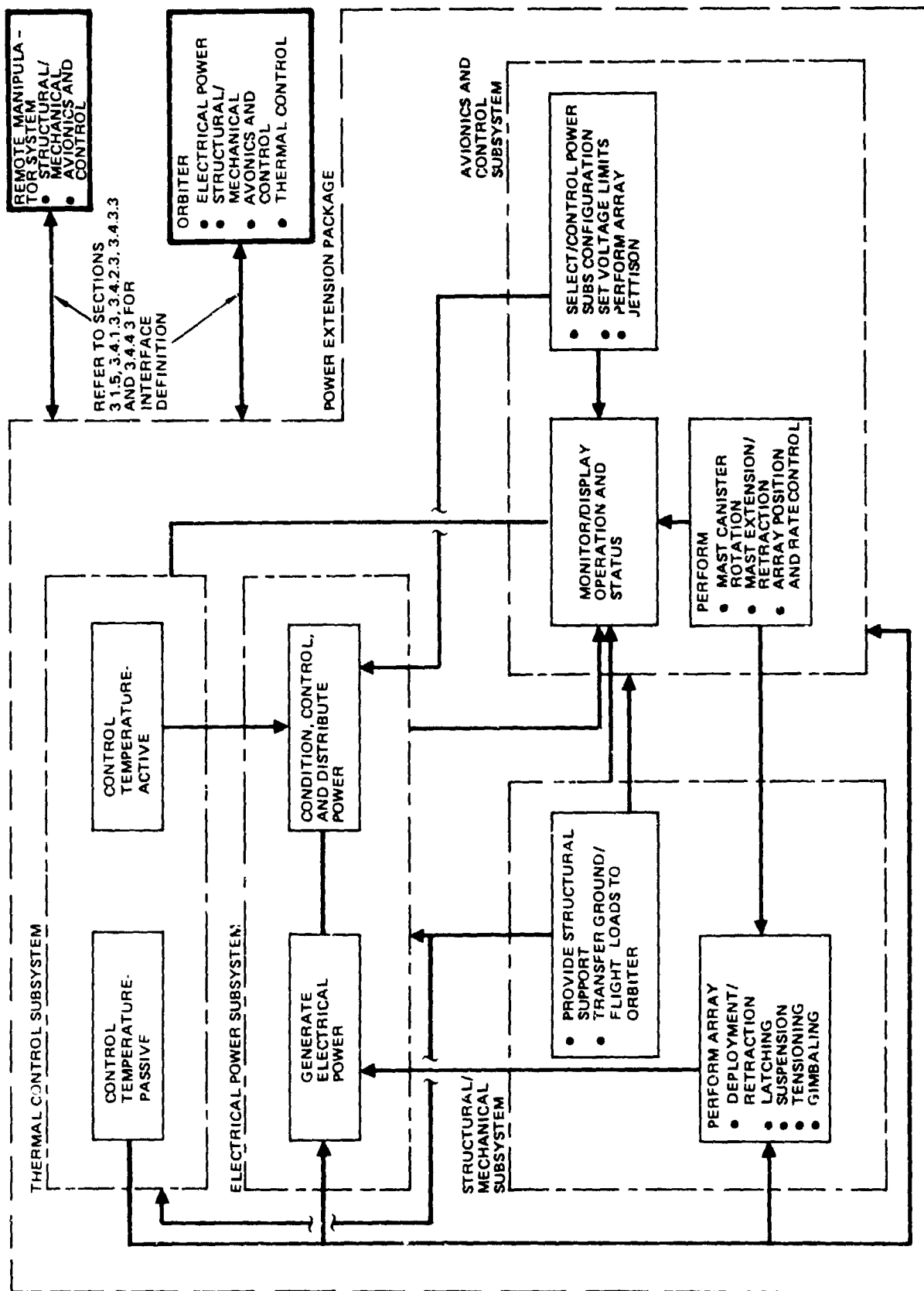


Figure 2. PEP Functional Block Diagram - System Level

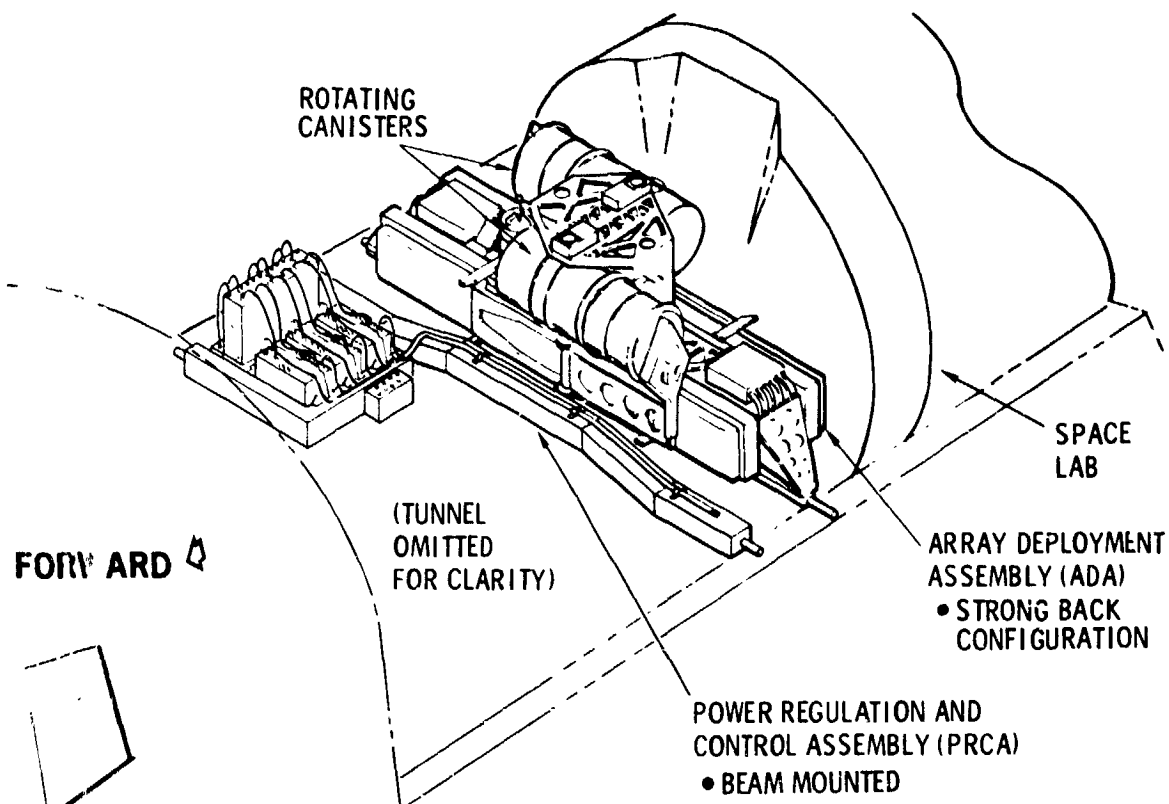


Figure 3. PEP Representative Configuration

ple fixture which mates with the RMS end effector and a gimbal assembly which allows positioning of the array for sun orientation.

The Power Regulation and Control Assembly (PRCA) provides regulation of the array electrical output for compatibility with the Orbiter bus. The PRCA also controls the Orbiter's fuel cells' operating power level with consequent control of cryogenic consumption rates.

The Interface Kit contains PEP to Orbiter and RMS interface provisions including ADA and PRCA support hardware, RMS power and data bus cables and electrical wiring harnesses.

Figure 4 illustrates PEP deployed from the Orbiter cargo bay for normal operation.

3.1.5 Interface Definition

Figure 5 is a top level diagram which identifies the existence of the various interfaces associated with PEP. These interfaces are categorized as "direct" and "PEP related." The direct interfaces are those actual functional and/or physical interfaces between PEP and:

Table 1. PEP Assembly and Subsystem Identification

Assembly	Subsystems			
	Electrical power	Avionics and control	Structural/mechanical	Thermal control
<u>Array Deployment Assembly</u>				
Solar Arrays	X			
Blanket Boxes			X	
Canister/Masts			X	
Core Structure			X	
Canister Support and Rotation			X	
Gimbal			X	
Sun Sensor and Control		X		
Instrumentation		X		
<u>Power Regulation and Control Assembly</u>				
Regulators	X			
Power Distribution Box	X			
Cold Plates			X	
Support Structure			X	
<u>Interface Kit</u>				
RMS Power Cable	X			
ADA Support Hardware			X	
PRCA Support Hardware			X	
Data Bus Cable	X			
Electrical Harnesses	X	X		
<u>GSE</u>	X	X	X	X

- Orbiter
- RMS
- Crew

The PEP related interfaces are those which do not directly interface with the PEP but which do allow the PEP functional interfaces or influence PEP-to-Orbiter interface characteristics. Categories include:

- Functional PEP interfaces:
 - Orbiter to RMS
 - Crew to Orbiter
 - Payload to Orbiter

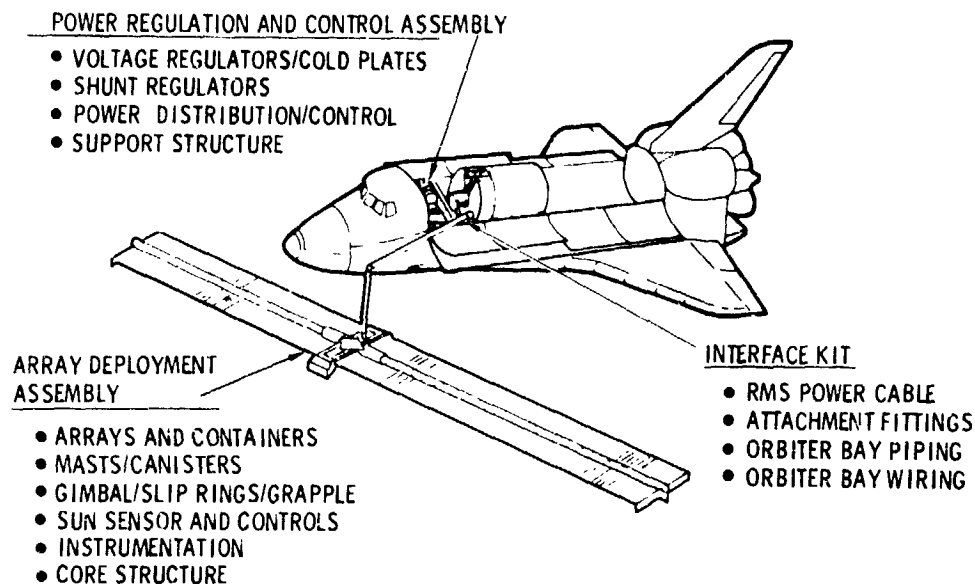


Figure 4. PEP Elements

- Influence PEP to Orbiter interface characteristics:
 - Tunnel to Orbiter
 - Spacelab to Orbiter

The PEP related interfaces are discussed in Appendix I to support the description of PEP direct interfaces described in Sections 3 and 4 of this specification.

An identification of all of the interfaces between PEP and the Orbiter, RMS and Crew is given in Figure 6. Here, the blocks labeled PEP, RMS and Orbiter are subdivided into elements that affect interface definition. The subdivision within the Orbiter and the RMS should be considered for reference only; they are identified here to facilitate understanding of total system interaction. Each is identified by a letter indicating whether a data (D), fluid (F), power (P), or structural/mechanical (S) interface exists and a listing number to aid in finding a typical design description in the Interface Definition Document - Power Extension Package SOD79-0117; Paragraph 4.0 Interfaces. The figure also categorizes each interface as "existing" or "new." Existing interfaces involve no modification to the Orbiter or RMS. Where existing interfaces do not apply, the Orbiter and RMS will accommodate PEP interfaces by means of "new" hardware modifications.

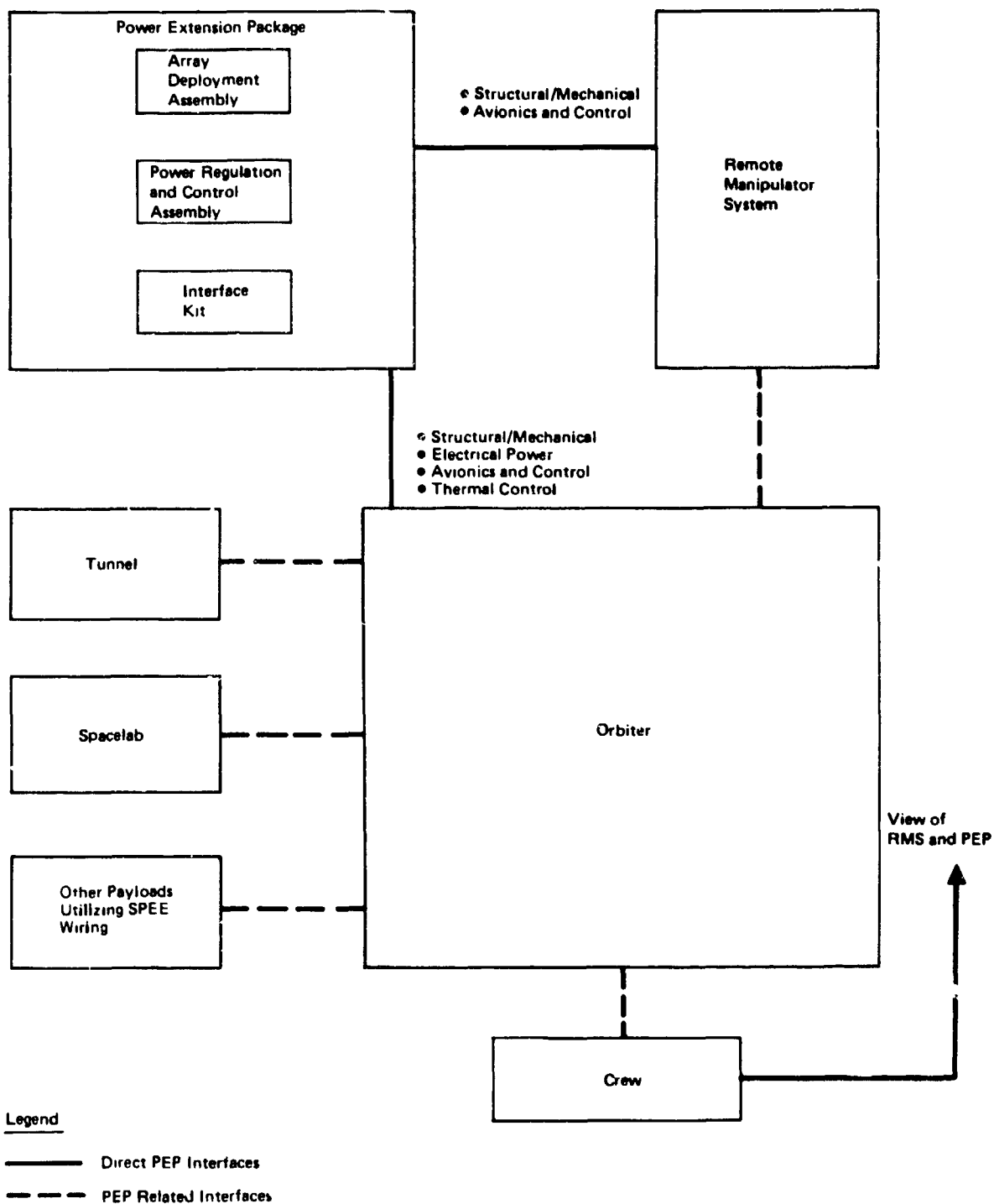


Figure 5. PEP System Interfaces – Top Level

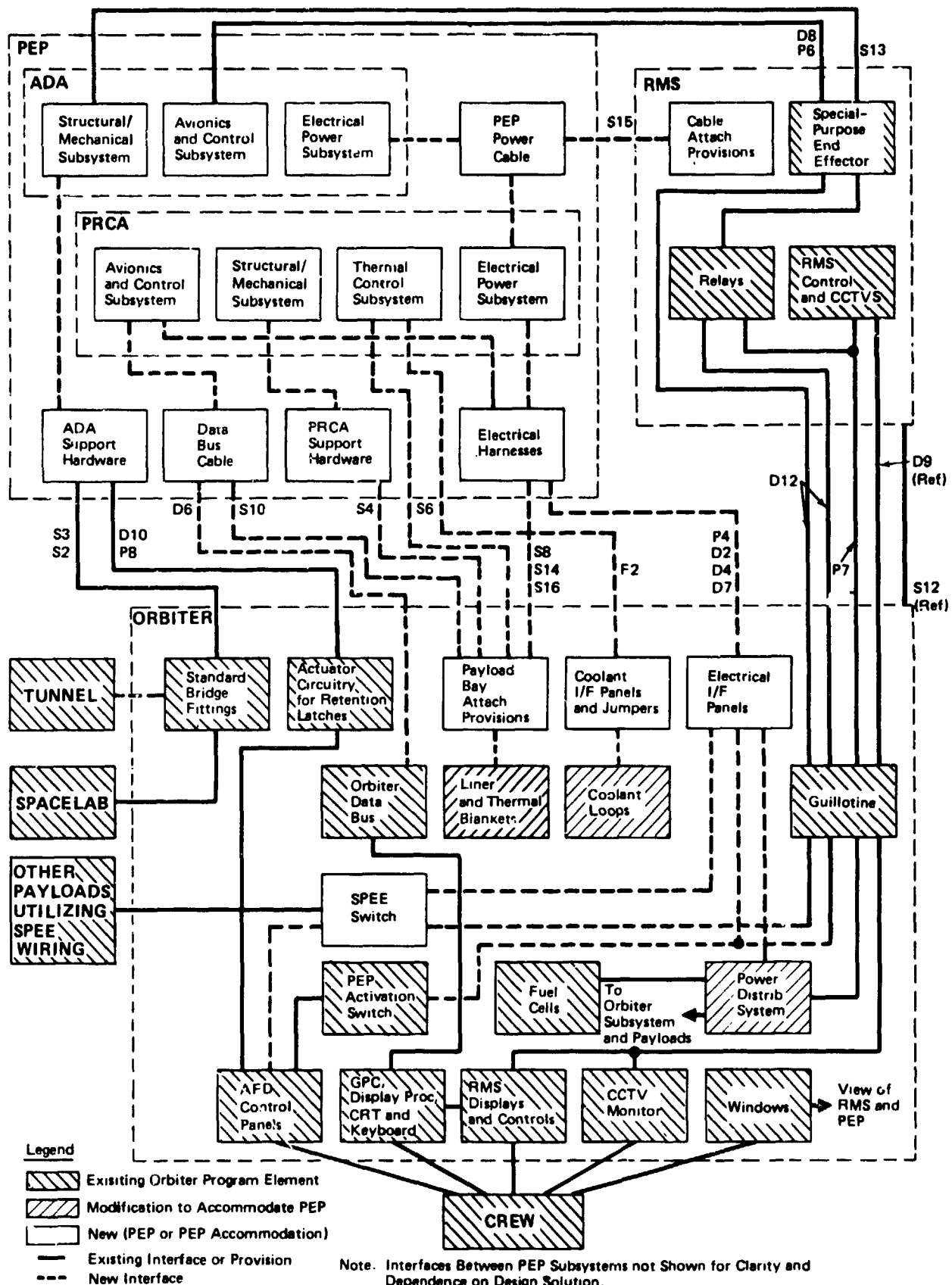


Figure 6. PEP System Interface Identification

Table 2 summarizes the interfaces and organizes them according to functional subsystem and assembly location. Most PEP to Orbiter and RMS interfaces are via the Interface Kit. A general description of the interfaces follows.

Referring to Figure 6, from left to right, these interfaces for PEP to Orbiter and RMS are:

PEP to Orbiter

S2, S3 - Mounting interfaces between ADA support hardware and Orbiter standard bridge fittings. The PEP side of the interface includes 3 retention latches (2 starboard, 1 port, S3) and a lateral load reaction fitting (starboard; S2). The Orbiter side of the interface includes 3 bridge fittings (2 starboard, 1 port). The port bridge fitting and the forward starboard bridge fitting are shared by the ADA and the tunnel. The aft starboard bridge fitting is shared by the ADA and the Spacelab. No keel interface exists. Relative deflection between Orbiter structure and PEP is accommodated by the PEP side of the interface.

D10, P8 - Electrical connector interfaces at each of above three PEP retention latches for power (P8) and command (D10). The Orbiter provides cable assemblies with mating connectors as standard payload provisions. The crew commands latch open and close functions on the AFD during ADA deployment and restowage operations.

D6 - Electrical connector interface between PEP data bus cable and Orbiter data bus. This interface provides the link between PEP equipment and an Orbiter GPC, display processor, CRT and keyboard for crew operation and monitoring of PEP.

S10 - Cable support interface between PEP data bus cable and Orbiter clamps provided in payload bay.

S4 - Mounting interfaces between PRCA support hardware and Orbiter cargo bay longerons. The PEP side of the interface includes two custom bridge fittings (one starboard, one port). The Orbiter side of the interface includes bolt holes and bonded spacers (to stand off bridge fittings from side walls). No keel interface exists. Relative deflection between Orbiter structure and PEP is accommodated by the PEP side of interface.

Table 2. Summary of Interfaces: PEP to Orbiter, RMS, and Crew

Item no.	I/F desig. no.	Assembly			Title
		ADA	PRCA	I/F kit	
Electrical power subsystem					
1.	D2			X	Voltage sensing - Orbiter busses A, B & C
2.	P4			X	Regulated power - Orbiter busses A, B & C
3.	S8			X	Regulated power harness mount
4.	S14			X	Voltage sensing harness mount
5.*	S15			X	PEP power cable mount
Structural/mechanical subsystem					
6.	S2			X	Yo reaction fitting mount
7.	S3			X	ADA retention latch mount
8.	S4			X	Custom bridge fitting mount
9.*	S13	X			RMS-ADA mate
Avionics and control subsystem					
10.	D4			X	PEP activation
11.	D6			X	PEP data bus coupler
12.	D7			X	ADA data/command
13.*	D8	X			ADA data/command
14.	D10			X	Latch command (starboard-2; port-1)
15.*	P6	X			ADA drive power
16.	P8			X	Latch power (starboard-2; port-1)
17.	S10			X	PEP data bus mount
18.	S16			X	PEP avionics harness mount
Thermal control subsystem					
19.	F2		X		Coolant supply/return - loops 1 and 2
20.	S6		X		Plumbing mount - loops 1 and 2
Other					
21.	-				Crew interfaces

Note: All interfaces are PEP to Orbiter except those indicated by asterisk (*) are PEP to RMS

S6 - Plumbing support interface between PRCA flexible coolant lines and Orbiter clamps provided in payload bay.

S8, S14, S16 - Electrical harness support interface between PEP electrical harnesses and Orbiter clamps provided in payload bay.

F2 - Self-sealing Freon 21 disconnect interfaces between PRCA thermal control subsystem and two coolant interface panels provided by the Orbiter in the cargo bay (one port, one starboard). The PEP side of the interface consists of four female connectors on flexible coolant lines that extend from the PRCA. The Orbiter side of the interface consists of four fixed, corresponding male connectors. Two connectors (one supply, one return) are located at each panel. For non-PEP missions, two jumpers are substituted for the PEP lines to provide flow continuity and appropriate pressure drops in Orbiter coolant loops.

D2, D4, D7, P4 - Electrical connector interfaces between PEP electrical harnesses and two electrical interface panels provided by the Orbiter in the cargo bay (one starboard, one port). The starboard panel includes the connectors for the following:

- A. Regulated power supply and returns from PEP to Orbiter power busses B and C (P4).

- B. Voltage sensing (and returns) of Orbiter power busses B and C by PEP (D2).

- C. Activation signal to enable PRCA to draw current through interface (A) above for initial activation (D4). The crew initiates this signal by a switch provided on the AFD.

- D. Data/command signals that link PRCA with ADA (D7). These signals are routed via Orbiter and RMS in order to utilize existing provisions and to enable sharing of SPEE wiring with another payload.

The port panel includes connectors for the following:

- E. Regulated power (and returns) from the PEP to Orbiter power bus A (P4).

- F. Voltage sensing (and returns) by PEP or of Orbiter power bus A by PEP (D2).

PEP to RMS Interfaces

Figure 6 identifies physical interfaces between PEP hardware elements and the RMS. These interfaces are:

S13 - Mechanical mate/demate interface between the RMS SPEE and the ADA structure. The PEP side of the interface utilizes a grapple fixture that is designed to mate with the RMS SPEE. The mate/demate operation is controlled and monitored by the crew from the AFD.

D8, P6 - Electrical connector interface between the RMS SPEE and the ADA Avionics and Control Subsystem. The PEP side of the interface is a connector integral with the grapple fixture identified in item S13 above. The electrical mating/demating occurs automatically as a result of the mechanical mating/demating. Through this connector are transmitted the data/command signals (D8) identified in D12, Appendix I, together with electrical power (P6) via the RMS relays.

S15 - Cable support interface between the PEP power cable and the attachment provisions on the RMS. The PEP side of the interface consists of the primary cables that transmit unregulated power from the ADA to the PRCA. The RMS side of the interface consists of clamps and bracketry designed to support the cables while permitting RMS joint movement. Mate/demate provisions at both ends of the cables are effected at the PEP side of the interface.

Detailed interface definition is provided in this specification for each of the PEP subsystems:

- Electrical Power - Paragraph 3.4.1.3
- Structural/Mechanical - Paragraph 3.4.2.3
- Avionics and Control - Paragraph 3.4.3.3
- Thermal Control - Paragraph 3.4.4.3

3.1.6 Government Furnished Property List

TBD

3.2 CHARACTERISTICS

3.2.1 Performance Characteristics

The PEP operating range will include all altitudes from 100 nm to 600 nm, and all orbit inclinations from 28.5 deg to 104 deg (the nominal Orbiter operating range).

Nominal orientation of the PEP array blanket is normal to the solar vector. To maintain this orientation, PEP employs a two-axis array gimbal. One axis can provide continuous rotation at orbit rates; the other adjusts for beta angle variations.

During PEP operations, the RMS joint brakes will be locked. Independent PEP controls employing a sun sensor to generate the pointing error signal will be used to track the sun.

In order to reduce drag and other aerodynamic effects at low altitudes, PEP shall have the capability to operate with the array blanket angled other than normal to the solar vector.

In nominal operations, PEP shall provide 26 kW electric power to the Orbiter and payloads at the beginning of life (BOL). Of this 26 kW, 10 kW will be made available to the payloads at Station 645, and 5 kW will be made available to the payloads at Station 603. The remaining 11 kW, when combined with 3 kW total fuel cell idle power will provide the 14 kW necessary for Orbiter operations.

Average PEP power usage, which is derived from the Orbiter busses, shall not exceed 200 watts. Peak power usage shall not exceed 400 watts while operating motors controlling canister/mast and mast extension/retraction functions.

The power and voltage characteristics of the PEP-fuel cell power system shall be maintained through orbital sunrise and sunset, as well as through any other shadowing of the PEP solar array.

PEP shall protect the Orbiter busses from the solar array's sunrise voltage surge.

PEP output voltage shall be controlled to cause the fuel cells to operate at 1 kW each when the PEP array is fully illuminated and normal to the solar vector. This requires a maximum voltage of 33 volts at the Orbiter busses.

3.2.2 Physical Characteristics

3.2.2.1 General Arrangements

The PEP system shall be designed as two primary assemblies; one assembly, Power Regulation and Control, shall be fixed in the Orbiter bay and contain voltage regulation and control equipment that interfaces with the Orbiter electrical and thermal control subsystems. The other assembly, Array Deployment, shall contain the solar array, deployment, and tracking equipment and be extracted from and returned to the Orbiter bay during the mission.

The ADA shall be fitted with a grapple fixture compatible with the RMS special purpose end effector (SPEE), see Figure 7, and be located within the reach pattern of the port side RMS when the assembly is stowed in the cargo bay. The stowed location of the ADA shall provide adequate visibility from the aft flight deck window for removal and restowage of the assembly using the RMS.

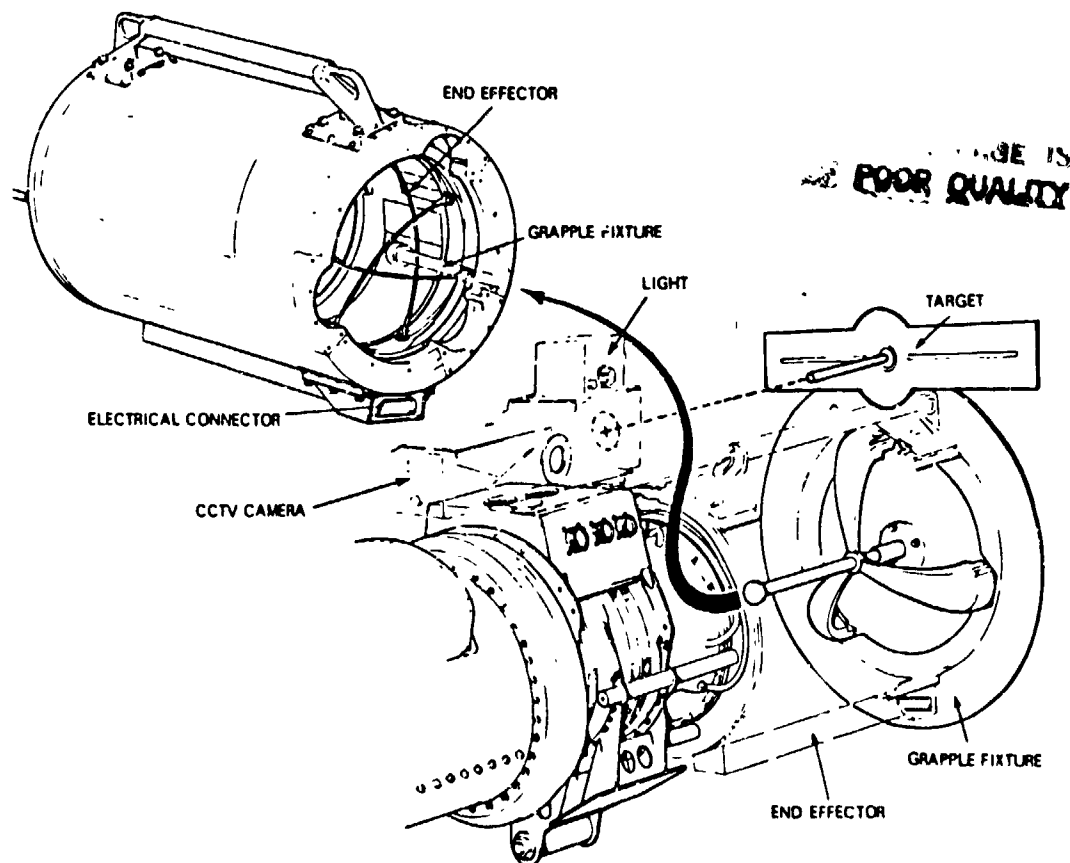


Figure 7. End Effector/Grapple Fixture Interface

PEP operations will use only the port side RMS; however, the PEP shall be compatible with the simultaneous installation of both port and starboard RMS's. The power transfer from the deployed array shall utilize a power cable attached to the external surface of the RMS.

The ADA shall incorporate a two-axis gimbal between the RMS end effector and the solar array to position the arrays with respect to the sun line.

The solar array assembly shall use a folding flexible substrate design packaged in two independently deployed arrays. The array shall be packaged to be stowed with the long dimension of the container mounted laterally across the Orbiter payload bay. Deployment/retraction of the two arrays shall utilize an articulated or collable longeron mast for each array.

Each mast, or mast and array package combined, shall be spring suspended between the gimbal assembly and the array. The suspension shall act both in the plane of the array and perpendicular to the plane of the array, to limit torques imposed on the array mast and RMS joints caused by RCS plume impingement on the array or by Orbiter accelerations. The suspension shall be locked out when the ADA is in a stowed configuration.

3.2.2.2 Envelope

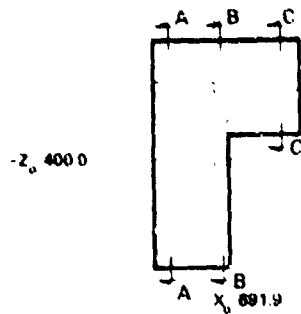
In the stowed configuration, the PEP, excluding Orbiter attachment provisions, shall not exceed the limits of the envelope defined by Figure 8 when exposed to the dynamic environments of Orbiter launch, reentry and landing.

The baseline stowage location is above the Spacelab short tunnel and between the Spacelab and the airlock. The envelope as defined is also compatible with the long tunnel and an all pallet payload. The PEP design shall not preclude stowage of the Array Deployment Assembly in other locations in the cargo bay. The aft limit of installation shall be established by the RMS reach limit. The design shall allow the installation of the ADA over the top of a standard payload pallet.

3.2.2.3 System Weight and CG

The PEP system shall be designed for minimum weight consistent with high reliability and low program cost. The target weight for the PEP, excluding attachment provisions to the Orbiter, is 2010 pounds (910 kg). This weight includes

X₀ 637.0 X₀ 681.5 X₀ 748.8



NOTES

1. THE ENVELOPE SHOWN DOES NOT INCLUDE TRUNNION INTERFACE WITH THE ORBITER. IN SECT C-C TRUNNION INTERFACE MUST OCCUR ABOVE STATION Z₀ 419 OR OUTSIDE OF THE EXTENSION OF THE 90R BELOW STATION Z₀ 419.
2. THE LIMIT STATIONS X₀ 748.8, X₀ 691.9 AND X₀ 681.5 ARE CLEARANCES FROM HANDRAILS ON THE SPACELAB TUNNEL AND AIRLOCK, RESPECTIVELY.
3. THE LIMIT STATION Z₀ 429 IS BASED ON TUNNEL AND TUNNEL STRUT DEFLECTIONS.
4. LIMIT STATION Z₀ 460 IS BASED ON AIRLOCK CLEARANCE.
5. LIMIT STATION X₀ 637 IS BASED ON MMU AND EVA ENVELOPE CLEARANCE.
6. LIMIT STATION Z₀ 414 BASED ON IGLOO CLEARANCE.

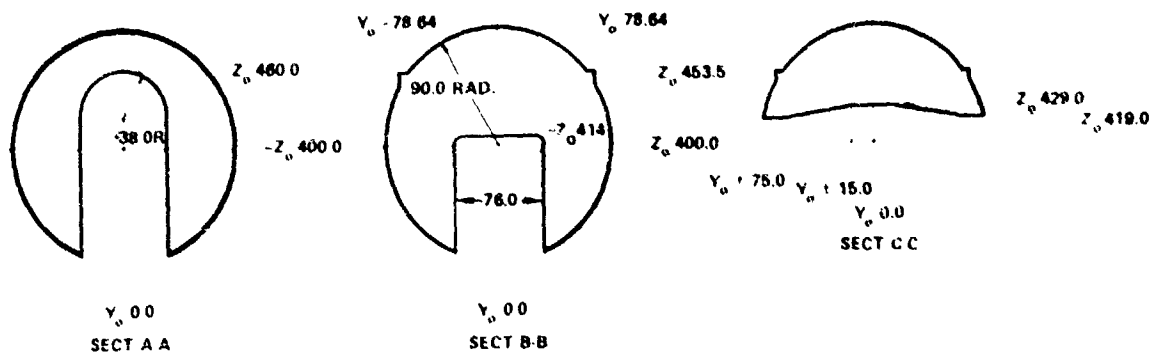


Figure 8. PEP System Stowed Maximum Dynamic Envelope

hardware permanently installed in the Orbiter and referred to as Orbiter scar weight. The PEI design shall minimize Orbiter scar weight consistent with PEP target weight considerations. The target for Orbiter scar weight is 53 pounds (24 kg) maximum.

The target weight for the PEP attachment provisions is 85 pounds (38.5 kg), which includes deployment latches, bridge fittings and journal fittings.

The center of gravity of the PEP system must be compatible with the Orbiter cargo bay CG constraints when flown in combination with any of the baseline payload configurations defined by Spacelab ICD 2-05101.

3.2.3 Environmental Criteria

The PEP system and its associated GSE shall perform in accordance with this specification and shall not incur damage during and after exposure to the natural and induced environments given in Table 3. The paragraph numbers listed in this table refer to those in the MDAC 1D23452 environmental specification.

Table 3. Natural and Induced Environmental Conditions
Applicable to PEP and Associated GSE

MDAC 1D23452, paragraph no., and environment	PEP	GSE
Natural environments		
Ground		
3.1.1 Transportation (Packaged)	X	X
3.1.2 Storage	X	X
3.1.3 Ground Handling Loads (Unpackaged)	X	X
3.1.4 Launch Site Operations Environment	X	X
Space		
3.2.1 Pressure	X	
3.2.2 Solar Radiation (Thermal)	X	
3.2.3 Solar Radiation (Ionizing)	X	
3.2.4 Meteoroids	X	
Induced environments		
Thermal environment		
4.1.1 Payload Bay Wall Temperature	X	
4.1.2 Entry Air Inlet Temperature	X	
Limit-load factors/angular accelerations		
4.2.1 Quasi-Steady Flight Events	X	
4.2.2 Transient Flight Events	X	
4.2.3 Emergency Landing Load Factors	X	
Acoustics, vibration, on-orbit accelerations		
4.3 Acoustics	X	
4.4 Vibration	X	
4.5 On-Orbit Accelerations	X	
Orbiter/cargo bay particulates and gases		
4.6.1 Purge Gas in the Cargo Bay	X	
4.6.2 Contamination	X	
Electromagnetic interference environment		
4.7.1 Shuttle Produced Interference Environment	X	
4.7.2 Cargo Produced Interference Environment	X	
RCS plume environment		
4.8 RCS Plume Environment	X	
Structural deflections		
4.9 Relative Structural Deflections	X	

3.2.4 Reliability

3.2.4.1 Definitions

The definitions presented in MIL-STD-721 shall be applicable to this specification, as appropriate.

3.2.4.2 Requirements

The PEP shall be designed and fabricated to satisfy the following reliability requirements.

A. The PEP shall be designed to satisfy the Orbiter payload reliability requirements.

B. The PEP on-orbit reliability design mission shall be 48 days inclusive of two cycles of ADA deployment and restowage in the Orbiter bay.

C. The PEP shall be capable of at least eight missions per year of a nominal 14 day duration, given appropriate maintenance.

D. The PEP shall be capable of performing a total of at least 240 array extensions and retractions with appropriate maintenance.

3.2.4.3 Reliability Design Criteria

The PEP shall be designed for graceful degradation (minor reduction in output or performance capability rather than system loss) in the event of item failure or damage to the solar array.

3.2.4.4 Operational and Storage Life

The PEP system shall be designed for operation and storage as shown below.

<u>Location</u>	<u>Time</u>
● On-Orbit (Operations)	3 Years Minimum
● Payload Bay (Launch/Reentry)	Approx. 50 Hours (Cumulative)
● Payload Bay - ETR	
— VAB	960 Hours (ETR ambient air)
— OPF	} Approximately 7 years
— Launch Pad	
● Storage - ETR (Hangar S)	

3.2.5 Maintainability

3.2.5.1 Maintainability Policy

The PEP system design shall be compatible with Orbiter operations and maintenance activities as follows:

A. The PEP system shall provide for checkout and monitoring on the ground (in the Orbiter) and for inflight performance monitoring.

B. Capability shall be provided to remove the PEP system at the launch pad.

C. Ground corrective maintenance actions while the PEP is onboard the Orbiter shall be limited to inspection and removal/replacement of line replaceable units (LRU).

D. There shall be no on-orbit preventive maintenance operations.

E. The PEP system shall minimize the need for special tools, fixtures, and test and support equipment for removal/installation, repair, maintenance, test and inspection.

F. The PEP design shall facilitate the tasks of external inspection and checkout with the Orbiter in either the horizontal or vertical position.

3.2.5.2 Design Provisions

The PEP system design shall provide for easy maintenance and efficient ground handling operations, and shall be responsive to the Orbiter specified turnaround time between flights, as follows.

A. The PEP system scheduled and corrective maintenance requirements shall be compatible with Orbiter scheduling.

B. The PEP design shall provide adequate access to, and tool clearance between, LPUs or components.

C. Wire bundle accessibility shall be provided without invalidating other wiring circuits of related equipments.

D. Electrical connectors shall be accessible without disassembly or removal of functional equipment.

E. Servicing and test ports shall be accessible without requiring removal of other than thermal protection covers.

F. The PEP wire harness on the RMS shall be removable in the field.

3.2.6 Transportability

The PEP system shall be designed for transportability in accordance with the

general requirements of Chapter 3 of NHB 6000.1C and the specific requirements of paragraph 3.1.1 of MDAC 1D23452.

3.2.6.1 Shipping and Handling Classification

PEP components, assemblies and system shall be defined as Class I items within the guidelines of NHB 6000.1C, Appendix A, with respect to the shipping and handling category.

3.2.6.2 Damage or Impaired Performance

The PEP shall not suffer damage or impaired performance when subjected to transport environments described in paragraph 3.1.1 of MDAC 1D23452.

3.3 DESIGN AND CONSTRUCTION STANDARDS

3.3.1 Materials, Processes and Parts

All materials, processes and parts shall be selected in accordance with the requirements of JSC-SE-R-0006 and shall be compatible with the performance and environmental criteria for the equipment as specified herein.

3.3.1.1 Flammability, Toxicity and Chemical Corrosion

A. Materials shall not be used which, when operating at temperatures up to the maximum anticipated in a mission, will generate toxic or noxious fumes, or dust, in such concentration as to impair Orbiter crew safety.

B. The PEP shall be designed with materials which are corrosion resistant or processed to resist corrosion. Metals of different composition shall not be used in intimate contact unless suitably protected against electrolytic corrosion.

C. Materials used in the construction of the PEP shall meet the criteria of NHB 8060.1.

3.3.1.2 Fungus Resistance

PEP materials shall be selected in accordance with MIL-STD-454, Requirement 4, to provide equipment capable of withstanding the deteriorating effects of moisture and fungus. Where necessary, suitable protective coatings may be used providing they retain their protective properties during the course of normal fabrication, handling, inspection, checkout, operations, and maintenance.

3.3.1.3 Lubricants

Lubricants shall be selected using NASA SP-8063 as a guide.

3.3.1.4 Outgassing

The selection of materials on exterior surfaces for use in the space/thermal environment around sensitive optical or thermal control surfaces shall be in accordance with JSC-SP-R-0022.

3.3.1.5 Parts Selection

Parts shall be qualified for space use. Off-the-shelf equipment shall be used wherever possible, and development of new equipment shall be minimized. The PEP design shall provide for maximum efficiency of equipment selection and/or development through multiple application of common items. Common items and their applications shall be identified, selected, and implemented in accordance with the commonality requirements of JSC 07700, Volume VII.

3.3.1.6 Contamination Control

Design, manufacturing, handling and operational concepts shall minimize the probability of contamination. The elimination or containment of all contamination sources, protection of the Orbiter flight crew from undesirable odors and toxic gases, and protection of sensitive equipment from space environment and operational sources of contamination shall be a design goal.

3.3.2 Electromagnetic Compatibility

The PEP shall be compatible with the Shuttle and cargo radiated and conducted interference levels specified in MDAC 1D23452. These requirements are not applicable to Ground System Test or Checkout Equipment.

3.3.2.1 Shuttle-Produced Interference Environment

PEP equipment operation shall not be impaired by Shuttle conducted and radiated interference levels specified in sections 4.7.1.1 and 4.7.1.2 of 1D23452.

3.3.2.2 Cargo-Produced Interference Environment

PEP equipment operation shall not be impaired by the cargo conducted noise and radiated field levels specified in sections 4.7.2.1 and 4.7.2.2. In addition, PEP-produced interference shall not exceed cargo emission limits.

3.3.2.3 Lightning Protection

Lightning protection shall be in accordance with JSC 07636. Lightning-produced fields shall be limited to a peak level of 70 A/m. The pulse will rise to peak in 2 microseconds and fall to zero in 100 microseconds. PEP equipment shall be designed such that a failure would not propagate catastrophically to the Space

Shuttle if a direct lightning strike should attach itself to the vehicle while in the launch configuration with the payload bay doors closed. These requirements are not applicable to Ground System Test or Checkout Equipment.

3.3.2.4 Inadvertent Electrical Shorting

The subsystem components shall be designed so that no electrical conducting surfaces are exposed to malfunctioning, shorting or inadvertent actuation due to floating debris or foreign material in any gravity state from 0 to 4 g's.

3.3.2.5 Protective Covers or Caps for Receptacles and Plugs

Captive protective covers or caps shall be provided for external electrical plugs and receptacles whenever they are not connected to the mating part.

3.3.2.6 Circuit Separation

Electrical circuits shall not be routed through adjacent pins of an electrical connector if a short circuit between them would constitute a single failure that would cause a loss of the mission.

3.3.2.7 Improper and/or Cross Connection Prevention

Connectors shall be designed to preclude improper mating and, where in close proximity to similar connectors, design shall preclude the capability of cross-connection. Electrical connections shall be designed such that they can be mated without pin damage, and can be visually verified.

3.3.2.8 Grounding and Isolation

The grounding and isolation of circuit returns for dc, plus the handling of shield grounds shall comply with the requirements of paragraph 10.7.4, Avionics Electrical Compatibility, TCD 2-19001.

3.3.2.9 Wire and Cable Installation

Wire and harness installations shall be designed so as to minimize potential damage. Wiring shall be protected by easily removable covers or other protective devices.

3.3.2.10 Cable Removal

Electrical cables and connectors shall be designed so that individual cables can be removed without disrupting the integrity of adjacent cables or lines and to facilitate replacement of electrical subsystem units such as a regulator.

3.3.3 Nameplates and Product Marking

All parts shall be labeled with a permanent nameplate listing as a minimum:

- Manufacturer
- Part Number
- Serial Number
- Date of Manufacture

3.3.4 Workmanship

Workmanship standards commensurate with space application requirements shall be employed.

3.3.4.1 Soldering

Soldering of PEP hardware shall conform to the guidelines of NHB 5300.4 (3A-1).

3.3.4.2 Welding

Resistance welding (spot and seam) shall conform to MIL-W-6858. Fusion welding for low-strength aluminum application and for materials other than aluminum shall be in accordance with MPD 164. Radiographic inspection of aluminum and magnesium welds shall be in accordance with MIL-STD-453. Welding aluminum for critical high strength applications, where maximum strength welds are needed, shall be in accordance with MSFC-SPEC-504. The technique of welding a joint from opposite sides shall not be utilized unless specific prior approval is obtained.

3.3.4.3 Castings

Castings shall be designed in accordance with MIL-A-21180. Use of castings shall be avoided where feasible. Penetrant inspection shall be performed in accordance with MIL-I-6866. Radiographic inspection shall be performed in accordance with MIL-C-6021.

3.3.4.4 Forgings

Forgings shall be designed in accordance with QQ-A-367. Penetrant inspection shall be performed in accordance with MIL-I-6866. Ultrasonic inspection shall be performed in accordance with MIL-I-8950.

3.3.5 Interchangeability

Mechanical and electrical interchangeability shall exist between like assemblies, subassemblies, replaceable parts, and components regardless of the

manufacturer or supplier. All components which have the same part number, regardless of the source, shall be functionally and dimensionally interchangeable.

3.3.6 Safety

The PEP shall be designed in compliance with the requirements of Chapter 2 of NHB 1700.7.

3.3.7 Human Engineering

MIL-STD-1472 and Sections 9.3 and 9.4 of JSC 07700, Vol. 14, shall be used as the principal human engineering references in the design of the PEP. As a minimum, the following features shall be provided to facilitate the man-machine interface operations.

- Self-alignment devices shall be provided for remotely connecting the RMS to the ADA for deployment.
- Quick disconnect capability shall be provided for remotely manipulated interface connections.
- Locks and latching mechanisms associated with array deployment/retraction shall have positive catch.
- Clear visual indications of remote latch status shall be provided to the Orbiter cabin, either directly or by existing Orbiter CCTV.
- Feedback shall be provided to the Orbiter cabin as to the status of deployment and retraction of the ADA.
- Obvious "NO-STEP" markings shall be provided to prevent damage to PEP equipment during ground maintenance.
- Exposed edges, corners and protrusions on the PEP shall meet the requirements of MIL-STD-1472, paragraph 5.13.5.4, and the following:
 - A. Exposed edges shall be free of burrs.
 - B. In the event a sharp edge cannot be avoided, it shall be guarded to prevent damage to a flight crew pressure suit.
 - C. If protrusions are necessary, they shall be designed to minimize the possibility of umbilicals being caught on them. Guards shall be provided, as necessary, to preclude entrapment.
- The on-orbit, in cargo bay, spacecraft lighting system provides the flight crew with adequate exterior illumination to monitor the deployment and operation of the PEP.

• Adequate crew restraints such as tethers, handholds, handrails, foot restraints and attachments shall be provided to allow zero g inspection and/or contingency servicing of the PEP system in orbit for both the stowed and deployed configurations.

• All equipment markings shall provide essential information to enhance ground and space crew performance and safety while performing PEP installation, checkout and maintenance or servicing tasks. Labels/checklists/nomenclature/color coding, etc., shall be designed in accordance with Section 5.5 of MIL-STD-1472.

• Control/display design criteria defined in MIL-STD-1472 are applicable for the control and monitoring systems associated with the PEP operations.

• All fasteners, handles, doors, levers, cranks, and other equipment that require operation by an EVA crewman shall have an actuation force of less than 155N (35 lbs.). An actuation force of 45N (10 lbs.) is preferred.

3.4 FUNCTIONAL AREA CHARACTERISTICS

This section provides the major PEP system functional requirements by subsystem. In addition, critical physical parameters and interfaces which are to be maintained are included. The system definition resulting from these data will assure compatibility with Orbiter requirements.

3.4.1 Electrical Power Subsystem

The electrical power subsystem consists of the solar array power source and those associated elements necessary for the regulation, distribution, and control of the power to the Orbiter/payloads and for PEP/Orbiter system protection.

3.4.1.1 Performance

3.4.1.1.1 Delivered Power--The PEP system shall deliver 26 kW BOL to the Orbiter and payloads (26.8 kW to the Orbiter interfaces) when illuminated with sunlight at 1353 W/m^2 and a sun angle (β), Section 6.2, of 50° during mid-orbital day.

3.4.1.1.2 Modularity/Flexibility--The power shall be delivered in at least three isolated blocks compatible with the Orbiter's three bus/fuel cell system; capability to allocate prior to flight up to 20% of the total power, in increments of 1%, between busses shall be provided. Maximum design power to any of the 3 isolated blocks shall not exceed 40% of the total power available.

3.4.1.1.3 Regulation--The power shall be delivered at a voltage compatible with maintaining the Orbiter fuel cells at a nominal 1 kW idle level (i.e., up to 33V maximum on Orbiter bus); the voltage shall be remotely adjustable, in increments of 0.02V from the aft operator's station over a range adequate to cover the variation in fuel cell characteristics and life degradation. In the event the Orbiter loads exceed the PEP capability, the PEP system shall deliver maximum available power, under the conditions specified in Section 3.4.1.1.1, and allow the fuel cell output to rise from 1 kW to a level adequate to supply the load.

3.4.1.1.4 Distribution, Control and Protection--The PEP system shall provide for:

A. Distribution of the power to the appropriate Orbiter interfaces. Section 3.4.1.3 of this document.

B. Control and monitoring of the PEP system operation including the provision of sufficient information to the Orbiter displays at the aft operator's station to allow manned supervision of the system.

C. Overvoltage protection of the Orbiter busses.

3.4.1.1.5 Parasitic Power--The PEP system shall not use in excess of 200 watts average.

3.4.1.1.6 Ripple--Maximum ripple on the PEP power lines interfacing with the Orbiter shall be per paragraph 3.3.1.1 of ICD 2-05301, Shuttle Vehicle/Spacelab Avionics interfaces.

3.4.1.1.7 Solar Array Degradation--Degradation of the PEP solar array shall not exceed 10% during eighty 14-day missions when flying either nominal mission mix specified below:

<u>Inclination</u>	ETR	WTR
	<u>% of missions</u>	<u>% of missions</u>
28.5°	78	0
55°	22	0
90-104°	0	100

3.4.1.1.8 Solar Array Output Voltage--The BOL and EOL peak power point output voltage of the solar array shall be in the range of 100-125 vdc under the con-

ditions of Section 3.4.1.1.1. The open circuit voltage shall not exceed 250 vdc BOL for the lowest temperature expected during orbital night.

3.4.1.1.9 Solar Array Short Circuit Current--The solar array short circuit current shall exceed 1.1 times the peak power current.

3.4.1.1.10 Solar Array Shadowing--The solar array shall not be damaged or permanently degraded when subjected to shadowing all or part of the wing area with the shadow moving at orbital rate.

3.4.1.1.11 Solar Array Instrumentation--Each solar array wing harness shall provide a minimum of 10 pairs of wires suitable for instrumentation use, running the full length of the array, and independent of the power cabling.

3.4.1.1.12 Solar Array Magnetic Forces--The solar array electrical circuits shall be designed to minimize magnetic forces on the Orbiter due to array currents.

3.4.1.1.13 Solar Array Power Transfer--Power shall be transferred from the solar array to regulation and control elements via the gimbal assembly and RMS cable installation described in Sections 3.4.2.1.6 and 3.4.2.3.2.

3.4.1.2 Physical
TBD

3.4.1.3 Interfaces

Figure 9 identifies interfaces that exist between the PEP Electrical Power Subsystem, the Orbiter and the RMS. Letter designations of these interfaces apply to both physical and functional characteristics as defined in SOD79-0117.

3.4.1.3.1 Orbiter--The PEP/Orbiter interface shall be in accordance with paragraph 4.1 of SOD79-0117, except that voltage at the busses shall not exceed 33 vdc.

A. Regulated Power - Orbiter Busses A, B and C: (P4) Designation--Physical and functional requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

B. Voltage Sensing - Orbiter Busses A, B and C: (D2) Designation--Physical and functional requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

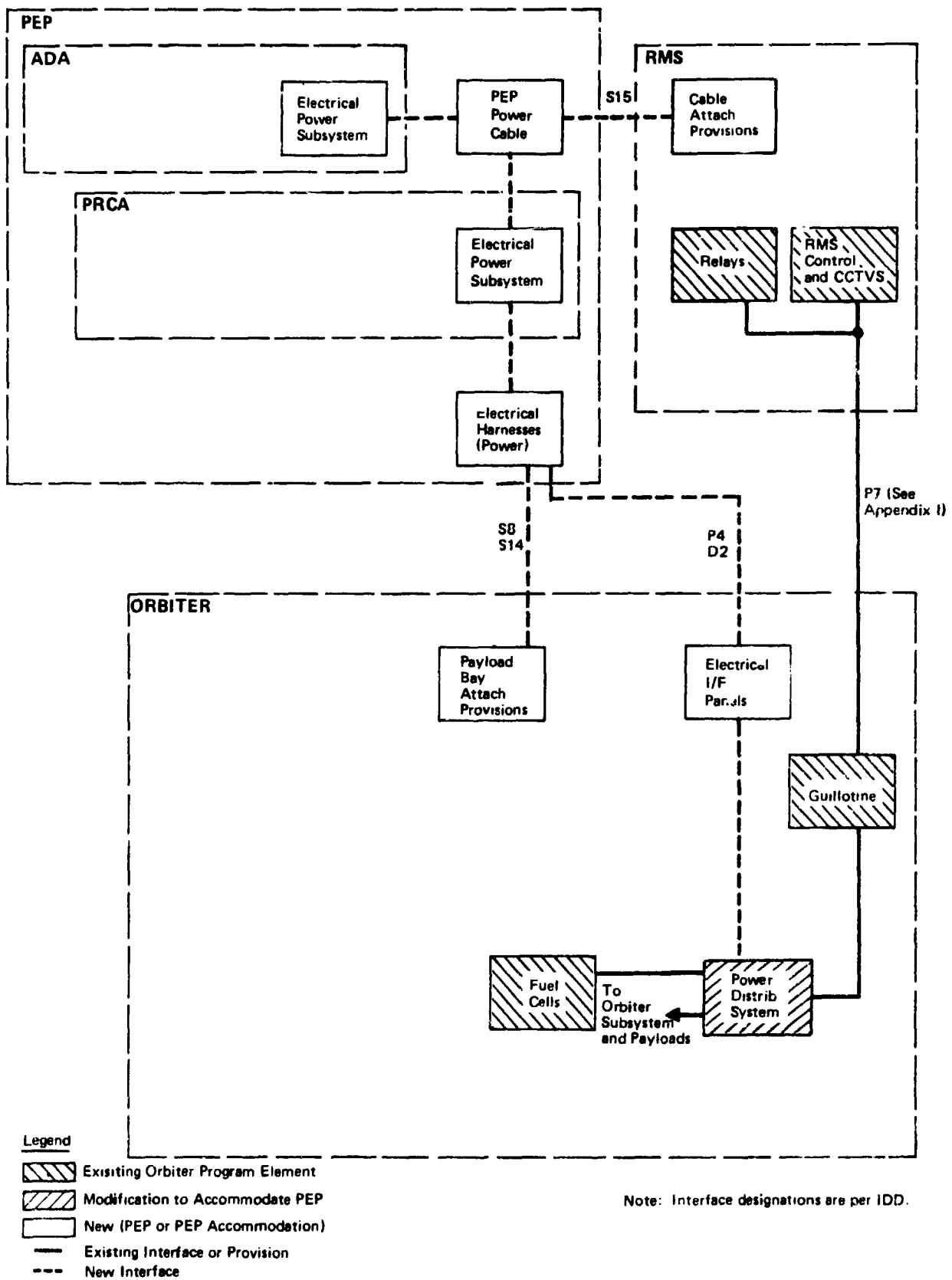


Figure 9. PEP System Interfaces - Electrical Power

C. Electrical Harness Mounts (Regulated Power Harness Mount and Voltage Sensing Harness Mount: (S8 and S14) Designations--The physical requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

3.4.1.3.2 RMS--The PEP/RMS interface shall be in accordance with paragraph TBD of SOD79-0117.

A. PEP Power Cable Mount: (S15) Designation--The physical requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

3.4.1.3.3 Crew--The PEP system shall be configured to allow selected monitoring and control from the crew station on the aft flight deck.

3.4.1.3.4 Launch Site Facilities and GSE--TBD

3.4.1.3.5 Subsystems--To be specified by the contractor during detail design.

3.4.2 Structural/Mechanical Subsystem

The Structural/Mechanical Subsystem shall be defined as the static structural elements that provide support and grouping of other subsystem elements and transfer ground and flight loads to the Orbiter structural interface plus, the active mechanisms, both mechanical and electro-mechanical, which provide the functions of array deployment, latching, suspension, tensioning, gimbaling, etc.

3.4.2.1 Performance

3.4.2.1.1 Strength--All structural elements shall be designed with a factor of safety equal to or greater than 1.4. The structure shall be capable of supporting ultimate loads from all critical loading conditions without failure. The stowed PEP elements shall be designed to the launch reentry and landing environment of Paragraph 3.2.3.

3.4.2.1.2 Life--All Structural/Mechanical elements shall be designed for a service life of 80 missions over a 10-year period, with an average mission duration of 14 days, maximum mission duration of 48 days and two deployment/retraction cycles during each mission. Active elements shall be designed to operate at their individual average duty cycle for the 80-mission life without

maintenance or refurbishment, static structure shall be designed with a fatigue life based on the 80 missions.

3.4.2.1.3 Array Deployment/Retraction Time--With the array deployment assembly positioned by the RMS external to the Orbiter cargo bay, the time required to completely deploy the array or conversely the time to completely retract and stow the array blankets in their containers shall not be more than:

A. Canister/mast rotation - 4 minutes, plus.

B. Mast extension (retraction) - 6 minutes.

Both array wings shall be deployed and retracted simultaneously.

3.4.2.1.4 Blanket Tension--Tension in the fully deployed solar array blanket shall be sufficient to prevent blanket contact with its support mast under all dynamic conditions imposed on the array.

3.4.2.1.5 Plume Loads--The fully deployed solar array wings shall be capable of withstanding direct impingement of Vernier Reaction Control System (VRCS) plumes. The plume pressure loading shall be based on the minimum separation distance between the thruster and the solar array plume for any mission condition and normal VRCS operation for Orbiter attitude hold control mode.

3.4.2.1.6 Array Pointing--Positioning of the array shall be accomplished in accordance with these requirements:

A. During PEP operation, the RMS joint brakes will be locked.

B. A two-axis gimbal (see Figure 10) shall be installed between the RMS end effector and the array.

C. The Alpha axis of the gimbal shall have continuous bidirectional tracking capability at orbit rate. The Beta axis of the gimbal shall have a travel capability of 90 deg minimum.

D. The gimbal assembly shall have the capability of maintaining the plane of the array perpendicular to the sun line within ± 2 deg for all mission orbits, orientations and attitude hold control modes.

E. The torque output of the gimbal shall be limited to a value less than the ultimate strength of the array support mast.

F. The gimbal assembly shall provide for transfer of the array electrical power and instrumentation and control signals across the rotating joints.

G. Separation devices for the electrical cables shall be provided between the PEP gimbal and the RMS end effector.

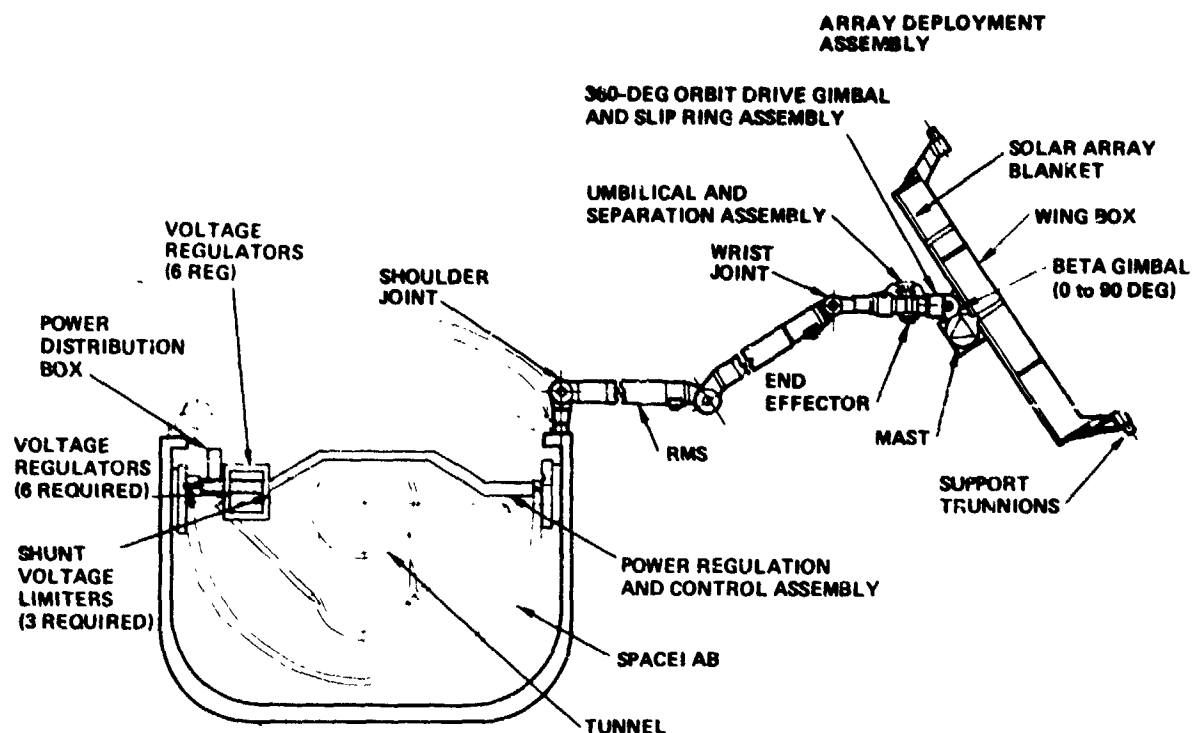


Figure 10. PEP Gimbal System -- Looking Aft

3.4.2.1.7 Dynamic Loads--With the array deployed by the RMS, the dynamic loads imposed on the RMS joints resulting from Orbiter stabilization, maneuver or VRCS plume loading shall be less than the torque required to back-drive the RMS joints. Operating restrictions may be considered in meeting this requirement.

3.4.2.2 Physical

TBD

3.4.2.3 Interfaces

Figure 11 identifies interfaces that exist between the PEP Structural/ Mechanical Subsystem, the Orbiter and the RMS. Letter designations of these interfaces apply to both physical and functional characteristics as defined in SOD79-0117.

3.4.2.3.1 Orbiter

A. The ADA retention latches, (S3) designation, and the Y_o reaction fitting, (S2) designation, shall interface with a standard Orbiter bridge fitting rail configuration in accordance with Paragraph 4.2.1 and Table 4.2 of

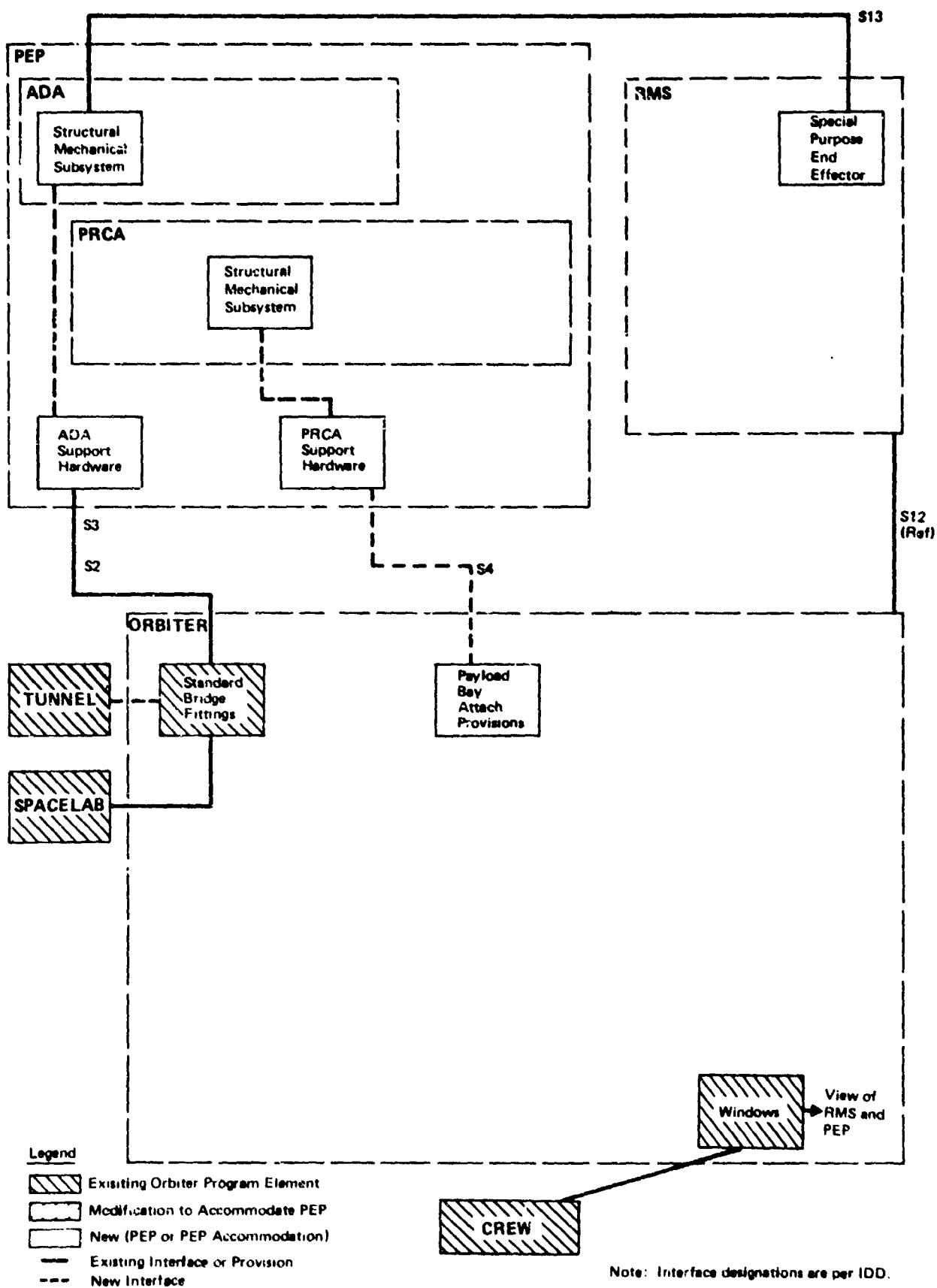


Figure 11. PEP System Interfaces -- Structural/Mechanical

SOD79-0117. The support of PEP assemblies shall make use of available existing standard bridge fittings installed for payload elements where possible.

B. The PRCA custom bridge fitting, (S4) designation, shall use the structural attach points provided in the Orbiter bay for payloads in accordance with Paragraph 4.2.2 and Table 4.2 of SOD79-0117. Special bridge fittings that interface with existing payload bay sill longeron and frame attach holes may be used.

3.4.2.3.2 RMS

A. The Array Deployment Assembly shall interface with the special purpose RMS end effector, (S13) designation, in accordance with Paragraph 4.4 and Table 4.7 of SOD79-0117. The cable used to transfer the electrical power from the array to the Orbiter shall be attached to the external surface of the RMS arm. The design shall minimize modifications to the RMS, and the cable shall have the capability of being installed and removed in the field.

B. The installation of PEP-related hardware on the RMS shall not interfere with the use of the RMS to perform its primary function when it is not being used to support PEP. The PEP power cable installation on the RMS arm shall not restrict any of the normal joint motions except wrist roll. The wrist roll motion shall be a minimum of $\pm 180^\circ$.

3.4.2.3.3 Crew--The overall PEP configuration shall be compatible with manual crew operation of the RMS to deploy and stow the ADA. Observation and control of these operations will be from the aft flight deck viewing windows.

3.4.2.3.4 Launch Site Facilities and GSE--TBD

3.4.2.3.5 Subsystem--To be specified by the Contractor during detail design.

3.4.3 Avionics and Control Subsystem

The Avionics and Control Subsystem performs the functions of electronic equipment activation, initialization, position and rate control of deployed elements, monitoring equipment status and providing crew interfaces for PEP command and status display. Manual and automatic means for the implementation of control functions are employed. Manual control is effected by crew insertion of values/limits for array rates and position with respect to RMS end effector coordinates and for configuration control of power bus contactors. Automatic control is effected by selection of the sun sensor for sun acquisition and tracking and through use of preprogrammed operational sequences and switch settings.

3.4.3.1 Performance

The Avionics and Control Subsystem shall be capable of performing the following functions:

- A. Activate/deactivate PEP pointing and control electronics equipment.
- B. Engage/disengage the power connector(s) between the RMS end effector and PEP grapple fixture.
- C. Rotate mast canister and extend/retract mast.
- D. Acquire and track the sun.
- E. Maintain the array axes in selected angular positions and/or rates with respect to the sun line and/or end effector axes.
- F. Select regulator and power distribution box configurations; i.e., connection/removal of power conditioning equipment from power busses.
- G. Set regulator/limiter voltage levels.
- H. Disconnect the Orbiter/PEP power bus interface to allow RMS jettison.
- I. Display PEP command status.
- J. Monitor and display PEP equipment operation .. status parameters.

PEP sun tracking shall employ a sun sensor with a minimum of $\pm 0.5^\circ$ resolution to provide an error signal for pointing control in two axes. The sun sensor shall provide a "sun presence" signal upon passage of the sun into the field of view. The sensor field of view and threshold setting shall prevent false lock-on due to sun "glint" from Orbiter-/PEP structure or earth's albedo.

The array pointing/control system shall maintain the array panels perpendicular to the sun line within $\pm 2^\circ$ after acquisition of the "sun presence" signal.

During that portion of the orbit in which the sun line is blocked by the earth and the "sun presence" signal is lost, the control system shall estimate or use predefined gimbal rates and command gimbal rotation in either direction such that a position error of no greater than $\pm 12^\circ$ between sun line and array face exists upon reacquiring the "sun presence" signal.

The pointing/control system shall provide torquer drive signals resulting in continuous rotation in one axis (Alpha gimbal) and 90° of travel, minimum, in the second axis (Beta gimbal).

The pointing/control system shall be capable of slewing both gimbals at minimum rates up to $0.5^\circ/\text{sec}$.

Slew rates commanded by the pointing/control system shall not result in static or dynamic structural loads which could damage the PEP or back-drive the RMS.

Power distribution to motors controlling canister/mast and mast extension/retraction shall be sequenced and controlled to limit total power supplied to deployed electronic equipment to 200 w maximum.

The time required for canister/mast rotation and mast extension/retraction (two wings) shall be in accordance with Section 3.4.2.1.3.

Commands input by the crew to effect manual or automatic control of PEP operation shall be displayed on the Multifunction Control and Display System (MCDS). PEP equipment status and/or operating parameters shall also be capable of display on the MCDS CRT.

Latch control of the ADA in its stowed position shall utilize the existing payload latch control system located on Panel A-6 of the on-orbit station.

Control signals for disengaging power or other cables at the PEP/ RMS shoulder to effect RMS/PEP jettison shall require an enable (arm) command preceding the disconnect (fire) command and be dual redundant. Should connectors fail to disconnect upon receipt of the first command set, the second set of command signals shall be sent within 10 seconds.

Control signals shall be provided to enable/inhibit the output of all regulators.

PEP reference voltage levels shall be adjustable on-orbit from the AFD. Setting accuracy increments shall be ± 0.01 volts minimum.

A capability shall be provided to check out PEP equipment and interfaces prior to removal of the ADA from the bay by the RMS. PEP status shall be made available to the crew and to Shuttle mission control via Orbiter telemetry. In addition, the values of individual measurements shall be available on request.

The PEP shall employ the Orbiter's Systems Management (SM) computer to format command and status display inputs to the MCDS.

3.4.3.2 Physical

The physical characteristics of the Avionics and Control Subsection are described in the following paragraphs.

PEP operation shall be remotely controlled from the Orbiter AFD.

Penetrations of the AFD bulkhead X₀ 576 shall be minimized.

3.4.3.3 Interfaces

Figure 12 identifies interfaces that exist between the PEP Avionics and Control Subsystem, the Orbiter and the RMS. Letter designations of these interfaces apply to both physical and functional characteristics as defined in SOD79-0117.

3.4.3.3.1 Orbiter--Physical and functional requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

A. PEP Data Bus Coupler: (D6) Designation--A digital interface between the PRCA avionics and the Orbiter data bus shall be provided for data acquisition and command output by the Orbiter SM general purpose computer (GPC). The PEP shall provide a data bus coupler to connect to the Orbiter-provided termination. Special twisted shielded pair wire shall be used for the coupler/ termination cable assembly. In addition, the following specific paragraphs of the IDD shall be satisfied:

1. Paragraph 4.1.2, Control Circuits
2. Paragraph 4.5, Orbiter Data Bus Interface (A11)

B. PEP Latch Power and Command: (P8, D10) Designations--Latch actuators shall be controlled and supplied power by Orbiter cable assemblies which contain two connectors per latch. Each connector shall provide dual latch open, closed and ready to latch talkbacks, three 28 v command inputs and 3 phase power. The following specific paragraph of the IDD shall be satisfied:

Paragraph 4.1.3, Orbiter Active Latch System.

C. PEP Data Bus Mount: (S10) Designation--Support for the data bus cable assembly shall be provided by the Orbiter. Cable clamps or other retention devices shall be easily removable using standard tools.

D. PEP Avionics Harness Mount: (S16) Designation--Mechanical support shall be provided for the avionics cable assembly between Orbiter connector A8J2 on bulkhead X₀ 576 and the PRCA. Cable clamps or other retention devices shall be easily removable using standard tools.

E. PEP Activation: (D4) Designation--A 28 VDC signal provided by a switch located on the on-orbit station standard switch panel shall be accessible at Orbiter connector A8J2 to activate/deactivate electronic equipment on the PRCA.

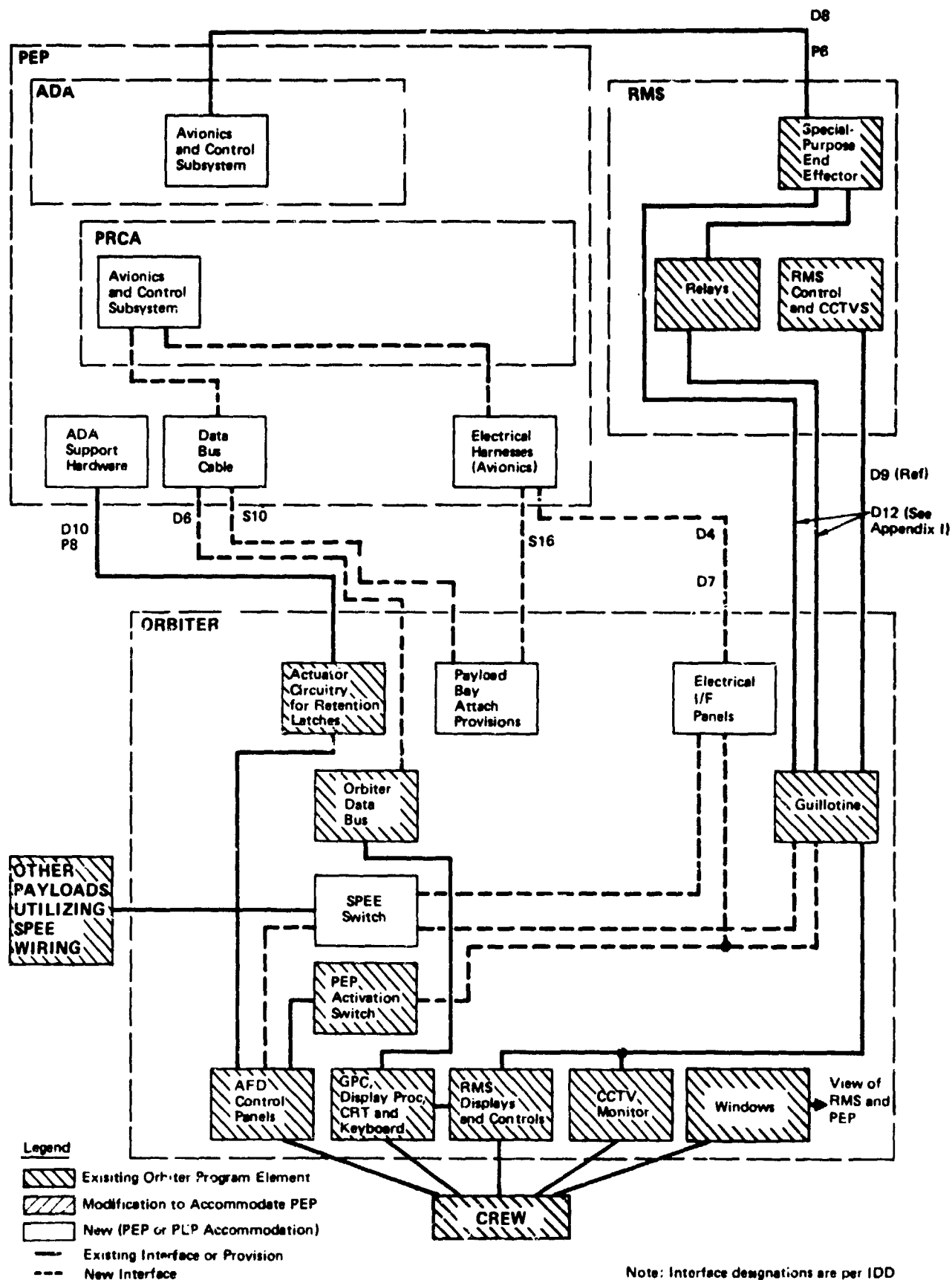


Figure 12. PEP System Interfaces – Avionics and Control

F. Array Deployment Assembly Data/Command: (D7) Designation--Control and data signals from/to electrical equipment on the PRCA from/to the SPEE switch shall be accessible at Orbiter connector A8J2. In addition, the following specific paragraphs/figures of the IDD shall be satisfied:

1. Paragraph 4.1.2, Control Circuits
2. Figure 4.1-1, Electrical Interfaces

3.4.3.3.2 RMS--Physical and functional requirements for the PEP side of this interface as defined in Table 4.7, SOD79-0117, shall be satisfied.

A. Array Deployment Assembly Data/Command: (D8) Designation--The continuation of RMS wiring (D12), see Appendix I, across the SPEE interface provides control and data signals to the ADA.

B. Array Deployment Assembly Drive Power: (P6) Designation--Existing relays within the RMS, when activated by D12 - Appendix I, provide power for the Power Connector Actuator and ADA equipment.

3.4.3.3.3 Crew--Crew interfaces are with the Orbiter MCDS, activation switch and the SPEE switch both on the on-orbit station.

3.4.3.3.4 Launch Site Facilities and GSE--TBD

3.4.3.3.5 Subsystem--To be specified by the contractor during detail design.

3.4.3.4 Software

Software for the PEP Avionics and Control Subsystem shall be resident in the SM computer and PEP equipment. Requirements for the SM software shall be furnished in a contract end item specification (CEI).

PEP software initialization and operation shall not require data transfer between SM and GN&C computers.

The PEP software function shall be operative during SM OPS 2 as a Specialist Function No. TBD and shall interface with the following:

A. Avionics equipment issue issuing command signals and acquiring data within the PRCA.

B. Avionics equipment processing data, issuing commands and acquiring data within the ADA.

C. The Table Maintenance Specialist function which provides the processing required to display or change, via keyboard input, selected PEP constants.

D. Systems software associated with items appearing on the PEP Specialist Display page and the MDCS.

Principal PEP functions to be performed by SM computer resident software include the following:

A. Executive Function (EXEC)--The EXEC function performs function initialization and calls the required principal functions in the proper sequence to execute the selected software mode.

B. Power Switching (PC) Control Function (PSCF)--The PC function prevents more than one regulator per bus having control authority, removes shunt regulators operating improperly from the busses and provides the power cable disconnect function in the event of an emergency.

C. Status Monitor (SM)--The SM monitors critical measurements obtained from PEP units in order to determine if anomalies exist in equipment operation. Information is provided to system software for CRT display of equipment status.

D. Sense Voltage Setting (SVS)--The SVS compares the regulator voltage settings to commanded values and commands changes to setting levels until agreement is reached.

The PEP software shall meet the following general functional requirements.

A. General Requirements

1. Initialize and self check the electronics equipment and all other interfaces with ADA mounted components when power is turned on.
2. Accept control commands and provide digital data and internal status to the Orbiter's Systems Management GPC.
3. Provide sequencing for canister rotation and mast extension/retraction.
4. Provide rotation drive levels for Alpha and Beta gimbals.

B. Functional Requirements

1. The PEP software shall execute in a microprocessor.
2. The microprocessor software program shall perform ADA sequencing and array gimbal control upon receipt of commands input to the keyboard of the MDCS. It shall examine a location in memory to determine its mode of operation.

3. Gimbal control modes are categorized as manual or automatic and shall consist of the following:

a. Manual Mode, Slew to Position - Causes the microprocessor to slew the arrays to given Alpha and/or Beta angles.

b. Manual Mode, Track at Constant Rate - Causes the microprocessor to slew Alpha and/or Beta gimbals at commanded angular rates.

c. Automatic Mode, Track Sun - Causes the microprocessor to maintain PEP array faces perpendicular to the sunline based upon data provided by a two axis sun sensor.

d. Automatic Mode, Trail Position - Causes the microprocessor to use sun sensor signal inputs in one axis while maintaining the other axis in a given angular position with respect to the Orbiter velocity vector.

4. A stop mode shall be provided which terminates the current ADA activity and causes the ADA to revert to a safe condition.

5. A test mode (disabled during flight) shall allow the loading and execution of special test software.

6. The software shall monitor external events via digital or discrete inputs and/or analog signals. These shall include latch positions, shaft encoder and sun sensor inputs. Provision shall also be made for monitoring solar array and other ADA component status and formatting and buffering this data for transfer to the GPC.

3.4.4 Thermal Control Subsystem

The thermal control subsystem shall maintain PEP equipment within temperature limits by active and passive means. PEP voltage regulators shall be actively cooled by a PEP Freon 21 loop which ties into the Orbiter aft cold plate loop. The various avionics components are passively thermal controlled by preferential location, surface coatings and electrical heaters.

3.4.4.1 Performance

The thermal control subsystem shall provide active cooling for PEP voltage regulators to maintain temperature within acceptable limits as determined by the Contractor.

PEP active cooling shall employ the Orbiter aft cold plate loop which shall be circulated through PEP cold plates. The PEP regulators shall be mounted on the cold plates.

PEP avionics shall be maintained within temperature limits by passive means such as special mounting provisions, surface coatings and electrical heaters.

3.4.4.2 Physical

PEP cold plates shall be designed to allow removal of either of the attached voltage regulators without removal of cold plates and without damage to fluid lines and components.

The thermal control subsystem when mounted to the PRCI shall be capable of being installed at any position within the bay with the provision of kits.

3.4.4.3 Interfaces

Figure 13 identifies interfaces that exist between the PEP Thermal Control Subsystem and the Orbiter. Letter designations of these interfaces apply to both physical and functional characteristics as defined in SOD79-0117.

3.4.4.3.1 Orbiter

A. Coolant Supply/Return - Loops 1 and 2: (F2) Designation--Physical and functional requirements for the PEP side of this interface as defined in Table 4.3, SOD79-0117, shall be satisfied. Specifically, Paragraph 4.3 of the IDD shall be satisfied.

B. Plumbing Mount - Loops 1 and 2, Cold Plate: (S6) Designation-- Physical and functional requirements for the PEP side of this interface as defined in Table 4.3, SOD79-0117, shall be satisfied. Specifically, Paragraph 4.3 of the IDD shall be satisfied.

3.4.4.3.2 RMS--None

3.4.4.3.3 Crew--None

3.4.4.3.4 Launch Site Facilities and GSE--TBD

3.4.4.3.5 Subsystems--To be specified by the Contractor during detail design.

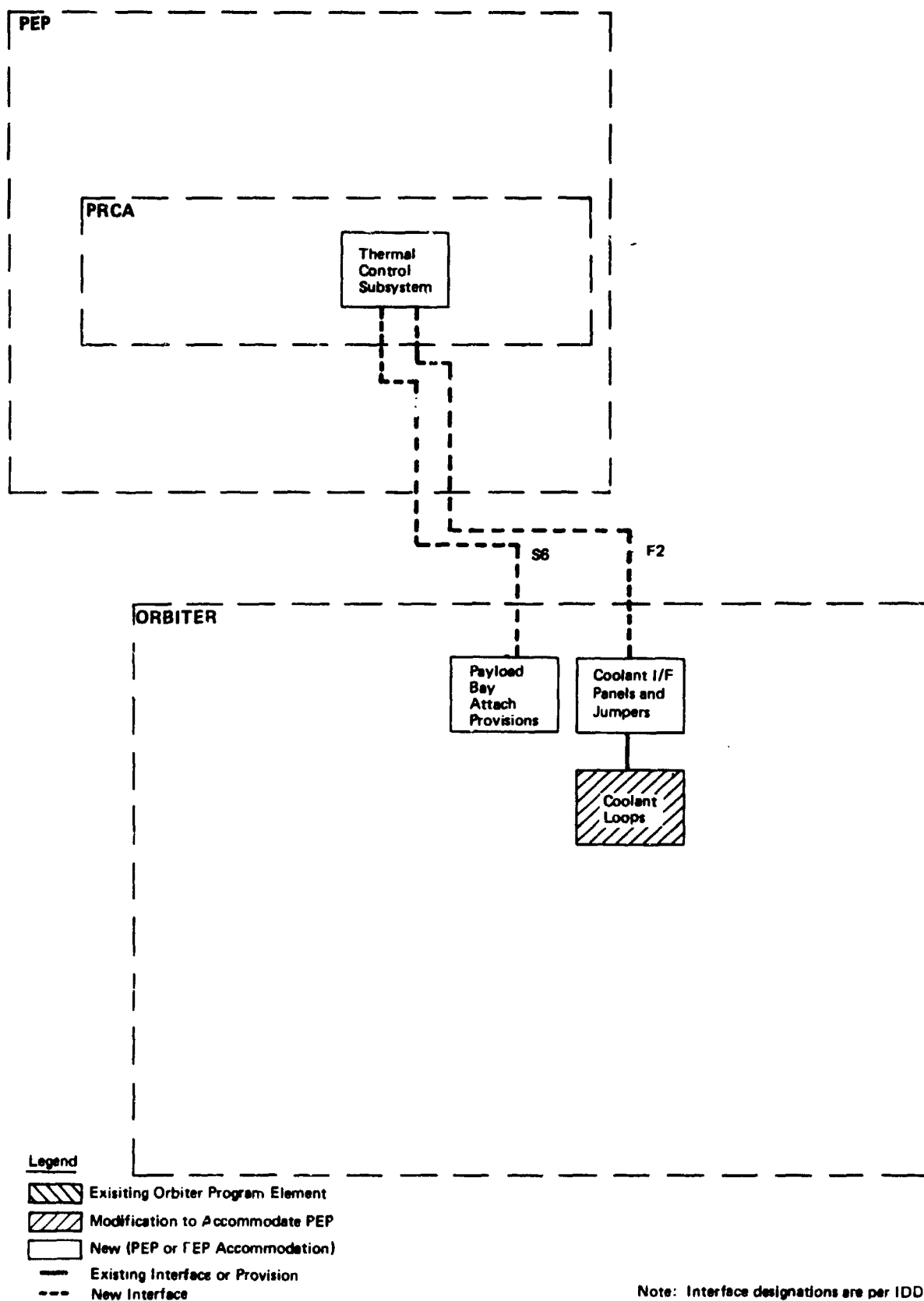


Figure 13. PEP System Interfaces - Thermal Control

3.5 GROUND SUPPORT

3.5.1 General Requirements

Ground support equipment (GSE) will be required to provide support and services to the PEP during integrated checkout and acceptance verifications at the factory plus prelaunch ground processing operations at KSC. These services will include electrical power, power distribution, cooling, controls and displays, real time data processing, recording of data and transportation and handling. Where practical and cost effective, the equipment design shall make maximum use of existing or modified end items and new hardware design shall be minimized. Where possible, government furnished equipment (GFE) will be utilized to satisfy GSE requirements. GSE shall be designed in accordance with the requirements in SE-0002.

3.5.2 Electrical Ground Support Equipment (EGSE)

The EGSE shall support PEP operations at the factory and launch site per requirements indicated in the following paragraphs.

3.5.2.1 Solar Array Power Simulator

A solar array simulator shall supply DC power to the Power Regulation and Control Assembly during PEP factory integrated testing and launch site checkout and interface verifications. Dual outputs (or dual supplies) shall be provided. Each output shall furnish 6.0 kilowatts of power over a range of 117 to 239 volts dc (approximately 52 amps at 117 volts or 25 amps at 239 volts).

Power outputs shall interface with the PEP power distribution cable on the RMS (or ground test equivalents).

3.5.2.2 Power Bus Load Simulator

A power bus load simulator shall provide loads for the PEP output buses, one bus at a time, during factory integrated test and launch site checkout.

A load capability of up to 11.0 kilowatts at 30 volts dc (approximately 370 amps) will be supplied. Loads shall be applied in three or four fixed increments or as continuously variable (or combinations thereof)

The simulator shall be manually connected one bus at a time at the Power Regulation and Control Assembly.

3.5.2.3 Canister Electrical Simulator

A solar array canister simulator shall provide electrical loads and feedback signals during PEP factory integrated testing and launch site checkout and interface verifications.

Mast deploy/retract motor loads shall be simulated for each of the two array wing canisters. Latch and deployment position feedback signals will be provided in the simulator for each canister.

The simulator will interface with the electrical control unit on the Array Deployment Assembly.

3.5.2.4 Interface Test Unit

An interface test unit will electrically simulate the Orbiter for data, controls and power during PEP factory integrated testing and launch site checkout.

Capability shall be provided for the following:

- 30 volts dc Orbiter power to PEP electronics
- Control and data monitor (digital interface)
- Operator interface for test operations
- Real time data recording (strip charts)

The unit shall interface with PEP electronics assemblies on both the Array Deployment and Power Regulation and Control Assemblies via test cables.

3.5.2.5 Orbiter Cable Simulator

An Orbiter cable simulator set shall replace the PEP-to-Orbiter interconnect wiring during factory integrated testing and launch site checkout and interface verifications.

All in-flight power, control and monitor functions shall be included between the following items:

- Solar Array (via Power Simulator) and PEP Power Regulation and Control Assembly.
- Array Deployment Assembly and Orbiter (via Interface Test Unit).

- Power Regulation and Control Assembly and Orbiter (via Interface Test Unit and Power Bus Load Simulator).
- Canister (via Canister Electrical Simulator) and Array Deployment Assembly electrical controls.

Cables shall be of sufficient length to interconnect the various units in a test configuration or with PEP installed in the Orbiter bay. The RMS/Array Deployment Assembly electrical disconnect shall be provided in the cable.

3.5.3 Mechanical Ground Support Equipment (MGSE)

The MGSE shall support PEP operations at the factory or launch site per requirements indicated in the following paragraphs.

3.5.3.1 Thermal Conditioning Unit

A thermal conditioning unit will provide cooling for the Power Regulation and Control Assembly equipment during factory integrated testing and launch site checkout.

A minimum of 1 kW thermal cooling will be provided by flowing Freon 21 through the Power Regulator and distribution cold plate coolant loop.

Connection with the cold plate fluid disconnects shall be via flexible lines provided with the unit.

3.5.3.2 Freon Leak Detector

A freon leak detector shall be provided to measure/detect freon leaks during factory integrated testing or launch site checkout and interface verifications.

The unit shall be in a portable hand held configuration and placed adjacent to freon lines and cold plates (no direct interface with PEP).

3.5.3.3 PEP Strongback

A PEP strongback shall provide the capability to simultaneously remove/install the PEP Array Deployment and Power Regulation and Control Assemblies in factory and launch site test fixtures, in CITE and the Orbiter payload bay.

The strongback will interface directly with PEP structure.

3.5.3.4 PEP Test Fixture

A PEP test fixture shall hold both the Array Deployment and Power Regulation and Control Assemblies during factory integrated testing and launch site checkout.

The fixture shall locate the PEP as close to the ground as practical to provide convenient personnel access to equipment.

3.5.3.5 PEP Transporter

A PEP transporter shall provide the capability to support and enclose the Array Deployment and Power Regulation and Control Assemblies during transportation between:

- Factory and ETR checkout facility
- ETR checkout facility and O&C Building
- O&C Building and OPF
- OPF and ETR checkout facility

Capability to include the attached PEP strongback during transportation shall be provided.

The transporter shall maintain a 100,000 class clean internal environment.

3.5.3.6 PGHM Adapter

A PGHM adapter shall provide the capability to remove the PEP from the Orbiter payload bay (vertical orientation) at the launch pad (for contingency operations only).

The adapter shall enable simultaneous removal of the PEP Array Deployment and Power Regulation and Control Assemblies via the PGHM.

3.5.3.7 Transportation Kit

A transportation kit shall provide a container for shipping various loose items associated with other GSE (fluid interconnect lines, test cables, hoisting slings, etc.).

3.6 PRECEDENCE

The requirements of this specification shall take precedence over all documents. Whenever a requirement is not explicitly specified in this document, a

suitable standard or specification shall be selected in the order of precedence indicated in the following paragraphs. The selection of a standard or specification of lower precedence shall be made only when standards and specifications from groups above it are not suitable for the application.

The Contractor shall notify the procuring NASA agency of each instance of conflicting or apparently conflicting requirements.

Document Groups by Precedence

Level I - Related Power Extension Package Specifications

Level II - Procuring NASA Agency Specifications and Documents

Level III - Other NASA Specifications and Documents

Level IV - Federal and Military Standards Listed in Department of Defense

Index of Specifications and Standards

Level V - Industrial Standards and Specifications Promulgated by Nationally Recognized Industry Associations, Committees and Technical Societies

Level VI - Company Standards and Specifications

Section 4
QUALITY ASSURANCE PROVISIONS

The PEP requirements of Section 3 of this specification shall be verified in accordance with the requirements and instructions presented in this section.

4.1 GENERAL

A. The methods of verification shall be as follows:

1. Inspection--Verifies conformance of physical characteristics to related requirements without the aid of special laboratory equipment, procedures and services.

2. Demonstration--Qualitatively verifies the required operability of equipment (or components thereof) by means which do not necessarily require use of laboratory equipment, procedures, items or services to indicate conformance to specified requirements.

3. Similarity--Verifies that PEP components satisfy their requirements, based on the certified usage under similar operating conditions.

4. Analysis--Verifies conformance to requirements based on studies, calculations and modeling.

5. Test--Qualitatively and quantitatively verifies the required operability of equipment (or components thereof) by technical means requiring use of laboratory equipment, procedures, items or services to determine conformance to specified requirements.

B. Test categories shall be those defined below:

1. Development tests--All non-recurring tests necessary to acquire engineering design information and confirm engineering hypotheses by use of test articles such as models, prototypes or preproduction systems and subsystems or equipment.

2. Qualification tests--All non-recurring tests necessary to demonstrate that hardware items will perform within required tolerances over the range of operational and environmental criteria delineated in the related and approved development specification and drawings. Also verifies effectiveness of the manufacturing process.

3. Acceptance tests--All recurring tests necessary to demonstrate that specific hardware items will perform as delineated in the related and approved product fabrication specification and drawings listed. Also verifies that the manufacturing process has not changed since qualification under Test Category 2 and that adequate quality control is being maintained.

4. Launch validation tests--All recurring tests necessary to demonstrate that each assembled PEP, when operating in conjunction with STS equipment and facilities, will perform within required tolerances over the range of operational and environmental criteria delineated in the related and approved product fabrication specification and drawings listed.

C. Except for tests requiring government facilities, testing shall be performed at the most cost effective location as determined by the contractor. For testing requiring government facilities or support, such as launch validation tests and in-flight qualification testing, the contractor shall notify NASA in time to assure PEP schedule compatibility.

4.1.1 Responsibility for Tests

Development, component and subsystem qualification, and acceptance tests shall be the responsibility of the contractor. Launch validation tests and the first on-orbit system qualification flight test shall be the responsibility of NASA with the contractor providing test support and analysis.

4.1.2 Special Tests and Examinations

4.1.2.1 Component Qualification Tests

Components shall be qualified by similarity where practical. Otherwise, testing shall be conducted to verify capabilities in the following environments.

- A. Thermal vacuum
- B. Thermal cycling
- C. Random vibration
- D. Acceleration
- E. EMC

4.1.2.2 Component Acceptance Tests

Component-level acceptance tests shall be performed on all components including spares and qualification test articles. Acceptance tests shall include the following environments.

- A. Thermal vacuum
- B. Thermal cycling
- C. Random vibration
- D. Burn-in (where appropriate)
- E. Lot sampling

4.1.2.3 Mass Properties

Component mass properties shall be determined and recorded.

4.1.2.4 Test Records

Adequate test records of all component acceptance testing shall be kept by the contractor in the form of data packages and shall be made available to NASA on request. These data packages shall contain the diagnosis and disposition of all failures. Failure analysis reports shall also be included. All failure analyses reports shall be available to NASA.

4.1.2.5 Subsystem Acceptance Tests

All subsystems shall be functionally verified and accepted at the contractor's facility prior to performing the system functional test. Testing shall be performed in a sequential manner such that subsequent tests do not invalidate prior tests. All failures, anomalies and discrepancies shall be corrected prior to the first functional test. As a minimum, the following criteria shall be established for acceptance test sequences:

- A. Any subsystem that is being tested must be of flight configuration.
- B. Normally, no components shall be removed after the test is completed unless the removal is part of a normally expected procedure.
- C. Removal of a component from the subsystem for any reason other than that normally expected invalidates all of the acceptance tests run on the subsystem and will require complete retest.
- D. All procedures must contain acceptance tolerance values for all data points to be verified and recorded.
- E. All subsystem tests must be run as an entity.
- F. Retest of a subsystem shall be required in the event of a failure affecting that subsystem during subsequent testing.

4.1.2.6 System Qualification Tests

PEP system qualification testing shall be accomplished on-orbit during the first flight.

4.1.2.7 System Acceptance Tests

PEP system level acceptance tests shall be performed to verify proper integration of the components and subsystems into the flight PEP system. Testing shall verify the following capabilities:

A. Functional

B. EMC

4.1.2.8 Launch Validation Tests

Launch validation testing shall be performed prior to each PEP-supported flight to verify operational integrity of the PEP.

4.2 QUALITY CONFORMANCE INSPECTIONS

Quality conformance inspection shall be performed in accordance with the requirements described below. Test specimens shall be identical to those of the flight articles. When environmental conditions cannot be properly or conservatively simulated in test, allowances for material properties, combined loading and other missing effects shall be provided in test procedures and applied loads. Where prior loading histories affect the adequacy of a test article, these shall be provided in test procedures and applied loads. Where prior loading histories affect the adequacy of a test article, these shall be included in all test requirements. Adequate instrumentation shall be provided in order to evaluate test results. All component level qualification testing shall be completed prior to shipment of the first PEP to ETR. Environmental acceptance testing of components shall be completed prior to the first installation of a PEP in an Orbiter. Environmental acceptance testing shall be performed on each qualification component prior to component qualification testing.

4.2.1 Requirements/Verification Matrix

A Requirements/Verification Matrix, Figure 14, shall be developed for the requirements of Section 3.

REQUIREMENTS/VERIFICATION MATRIX															
VERIFICATION/TEST LEVEL				VERIFICATION/ASSESSMENT METHOD						VERIFICATION BY SIMILARITY					
DEV - DEVELOPMENT QAL - QUALIFICATION EFF - EFFECTIVENESS ACC - ACCEPTANCE				ANL - ANALYSIS INS - INSPECTION DEM - DEMONSTRATION O/T - OPERATIONAL TEST TBR - TO BE RECOMMENDED BY SUPPLIER AS PART OF BID ANALYSIS. (TBR MAY BE USED ONLY ON BID ANALYSIS RELEASE)						NA - NO ADDITIONAL VERIFICATION DETAILS REQUIRED					
NR - NO REQUIREMENTS IN THIS PARAGRAPH TO BE VERIFIED															
SECTION 3 REQUIREMENTS PARAGRAPH		VERIFICATION											SECTION 4 VERIFICATION PARAGRAPH		VERIFICATION BY SIMILARITY
		NR	VERIFICATION/ TEST LEVELS				VERIFICATION/ ASSESSMENT METHOD					NA			
		DEV	QAL	EFF	ACC	ANL	INS	DEM	O/T	TBR					

MCDONNELL DOUGLAS ASTRONAUTICS CO.
HUNTINGTON BEACH, CALIF.

MCDONNELL DOUGLAS

SIZE	CODE IDENT NO.	DRAWING NO.
A	18355	
SCALE	REV	SHEET

90-0213-1A25 (18 DEC 71)

Figure 14. Requirements/Verification Matrix

4.2.2 Qualification Certification

Qualification test summaries, related to 4.1.2.1 and 4.1.2.5, shall be prepared by the contractor for NASA approval for all items requiring qualification. As a minimum, these summaries shall include.

- Part identification
- Test requirements identification
- Test procedures identification
- Test schedule and progress
- Documentation of test anomalies

Section 5 PREPARATION FOR DELIVERY

5.1 GENERAL

Supplier of PEP equipment shall be responsible to prevent corrosion, deterioration, physical damage and to ensure safe delivery in good condition. Caps, plugs, or other methods shall be provided to prevent the entrance of foreign materials to threads and mating surfaces (i.e., fluid lines).

5.2 PRESERVATION AND PACKAGING

PEP equipment shall be cushioned and packaged in accordance with NHB 6000.1C, Chapter 2 to maintain quality of materials during shipment from supply source to the first receiving activity at the ETR. Specific PEP transportation environments are delineated in the PEP Environmental Specification (MDAC 1D23452) Paragraph 3.1.1.

5.3 PACKING

PEP equipment packaged per 5.2 shall be packed in a manner to assure carrier acceptance at the lowest freight rates, and to assure safe delivery from supply source to the first receiving activity at the ETR.

5.4 MARKING

All containers shall be marked in accordance with NHB 6000.1C, Paragraph 212.

5.4.1 Non-Government Agencies

Unit, intermediate, and shipping containers shall be durable and legibly marked with a minimum of the following information.

- A. Part number
- B. Order number
- C. Manufacturer's name or identification code number
- D. Hardware quantity

5.4.2 Governmental Agencies

In addition to the marking required by Paragraphs 5.4 and 5.4.1, direct shipments to governmental agencies shall be marked in accordance with MIL-STD-129.

Section 6

NOTES

6.1 ABBREVIATIONS AND ACRONYMS

A/m	Amperes/meter
ADA	Array Deployment Assembly
AFD	Aft Flight Deck
ASSY	Assembly
BOL	Beginning-of-Life
CCTV	Closed Circuit Television
CEI	Contract End Item
CG	Center of Gravity
CITE	Cargo Integration and Test Equipment
CRT	Cathode Ray Tube
DC	Direct Current
EGSE	Electrical Ground Support Equipment
EOL	End-of-Life
ETR	Eastern Test Range
EVA	Extravehicular Activity
GFE	Government Furnished Equipment
GPC	General Purpose Computer
GSE	Ground Support Equipment
ICD	Interface Control Document
IDD	Interface Definition Document
I/F	Interface
IVA	Intravehicular Activity
kW	Kilowatt
KYBD	Keyboard
LRU	Line Replaceable Unit
MCDS	Multifunctional CRT Display System
MCIU	Manipulator Controller Interface Unit
MDA	Main Distribution Assembly
MGSE	Mechanical Ground Support Equipment

MTBF	Mean Time Before Failure
MTTR	Mean Time to Repair
N	Newtons
nm	Nautical Mile(s)
O&C	Operations & Checkout
OPF	Orbiter Processing Facility
P	Nominal Array Capability
A	
PEP	Power Extension Package
PGHM	Payload Ground Handling Mechanism
PRCA	Power Regulation and Control Assembly
PRCS	Primary Reaction Control System
RHC	Rotation Hand Controller
RMS	Remote Manipulator System
SM	Systems Management
SPEE	Special Purpose End Effector
STS	Space Transportation System
SVS	Sense Voltage Setting
SWAT	Space Wide Angle Telescope
THC	Translational Hand Controller
VAB	Vertical Assembly Building
vdc	Volts Direct Current
VRCS	Vernier Reaction Control System
V	Nominal Voltage Set Point
S	
WTR	Western Test Range
w/m ²	Watts per Square Meter

6.2 DEFINITIONS

Alpha axis--The axis of the PEP gimbal system which is maintained perpendicular to the orbit plane and may be driven up to orbital rate to align the array axis perpendicular to the sun from sunrise to sunset.

Beta axis--The axis of the PEP gimbal system which is fixed parallel to the plane of the array and is driven from 0 to 90° to align the plane of the array perpendicular to the sun line.

Contractor--The commercial business which receives contract award from NASA to perform in accordance with this PEP System Specification.

External turnaround checkout--Complete inspection and detailed checkout of the PEP including sending of the array to the vendor for cleaning, inspection and electrical checks and returning it to the using agency.

Operational checkout--Time required to turnaround the PEP from the time of removal in the OPF through transportation to the OPF for next flight installation.

Sun angle (β)--The angle between the sun line and its projection on the orbit plane.

Sun line--A line from the sun to the array.



APPENDIX I

PEP-RELATED INTERFACES

A.1 SCOPE

This appendix contains a description of the PEP-related interfaces which:

- Support the functional operation of the PEP to Orbiter and RMS interfaces and/or

- Affect the characteristics of the PEP to Orbiter interfaces

This information is provided to permit a clear understanding of the interface descriptions provided in Sections 3 and 4 of the specification.

A.2 GENERAL

The RMS represents the means of communication between the deployable (ADA) and fixed (PRCA) assemblies of the PEP. This communication is further routed via the Orbiter in order to utilize standard provisions. (For example, in the event the RMS must be jettisoned for safe Orbiter return, wiring is severed by the Orbiter guillotine.)

In addition to crew operation of the RMS via the Orbiter, crew operation and monitoring of the PEP utilizes display and control provisions at the AFD crew station. Included among these provisions is viewing through windows and via CCTV monitors.

Interfaces of the Orbiter with the tunnel and with the Spacelab are important to PEP because of envelope considerations and because these elements share the use of Orbiter bridge fittings with the ADA. In the case of the tunnel, the existing tunnel bridge fittings will not accommodate the ADA and therefore are replaced with Orbiter standard bridge fittings available for payload application.

During operation, the PEP utilizes the RMS and its SPEE wiring. If another payload on the same mission requires use of the RMS, the ADA may be temporarily restowed in the Orbiter cargo bay and the RMS freed for other

usage. If this payload also requires use of the RMS SPEE wiring, then a means of switching (or sharing) is provided within the Orbiter. Such provision, while not currently standard, is also required to support two or more such payloads on a non-PEP flight.

A.3 ORBITER TO RMS INTERFACES

Figure 6 identifies physical interfaces between the Orbiter and the RMS. While these physical interfaces do not affect PEP directly, some of the corresponding functions apply. From left to right, these interfaces are:

D12 - Electrical connector interface at RMS shoulder. This is a standard provision, utilized in this case to transmit the data/command signals identified in D7 (Paragraph 3.1.5) from the Orbiter to the RMS.

D12 - Electrical connector interface at RMS shoulder. This is a standard provision utilized in this case to transmit an activation signal to the RMS relays, that enables ADA to draw current via the interfaces identified in P7 and in P6 (Paragraph 3.1.5). The crew initiates this signal by the same AFD switch identified in D4 (Paragraph 3.1.5).

P7 - Electrical connector interface at RMS shoulder. This is a standard provision that supplies power for normal RMS functions. In this case, power is also supplied to the RMS relays, identified in D12 above.